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ORIGINAL ARTICLES.

I.—Some Notes on the Geology of the Bermuda Islands.

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(PLATES XXI–III.)

(*Concluded from the September Number*, p. 395.)

(4) *Recent Æolian Sands.*—On the south shore the sand has made or is making some encroachments on the land, in others on the sea. The 'live' sand-dunes are principally to be found at Tuckerstown, but there are some movements at Elbow (or Middleton) Bay and at Warwick Long Bay. The shell-sand is mostly made up of the broken shells of various marine species, some few being entire, with which are mingled the broken tubes of serpulæ, fragments of nullipores and corallines, and the red shells of a *Vermetus*, viz. *Teganodus* (*Siliquaria*) *ruber*, Schum. This latter is so plentiful as to give a distinctly red appearance to the sand of some beaches.

The coarsest sand on the islands (according to Mr. Richard Kempe, who has lived in the islands since 1848) occurs at Astwood's Bay, in Warwick parish. In other bays the sand varies in size of grain, and a great deal of the finer material is no doubt derived from the degradation of the former coast and cliffs. The present cliffs on the south shore are from 30 to 50 feet high. The former shore extended seaward to a distance of a little over 300 to rather over 700 yards from the present shore-line. The erosion of this coast must have commenced before the deposition of the Devonshire formation, which Verrill places in the Champlain or Post-Glacial Period.[1] The Devonshire Beds at Hungry Bay abut on the eroded Walsingham rocks.

The blown sands act as protectors of the present cliffs, as at Warwick Long Bay, where a chain of sand-dunes, 'anchored' by such plants as sea-lavender (*Tournefortia gnaphaloides*, R. B.), indigo-berry (*Randia aculeata*, L.), and crab-grass (*Stenotaphrum Americanum*, Schr.), are a distinct advanced guard, and, by keeping together the sand, prevent the further inroads of the sea (see Plate XIX). At the same time there are occasional extensive falls of the higher cliffs, as at Kempe's Bay (Pl. XX, Fig. 1), where at the time of my visit some 100 tons or so of the loosely compacted Paget Beds had fallen to the present beach. It is such falls that account for the land shells (*Pœcilozonites Bermudensis*, var. *zonatus*, Verrill) which occur on the marine beach (Text-fig. 4).

[1] Verrill, "The Bermuda Islands: Geology": Trans. Conn. Acad. Arts Sci., vol. xii, p. 75.

Sir Wyville Thomson[1] described an encroachment of sand at Elbow Bay, to which he applied the name of sand 'glacier' (July, 1873). He describes the steady progress of this destructive invasion, covering cultivated land, overwhelming a house, and advancing through a wood of 'cedars' (*Juniperus Bermudiana*, L.). Since 1873, however, this sand 'glacier' has ceased to advance landward. Various plants, such as the grape-mangrove (*Coccoloba uvifera*, L.), the seaside vine (*Ipomœa pes-caprœ*, Sweet), the bay-bean vine (*Canavalia obtusifolia*, D. C.), burr-grass (*Cenchrus tribuloides*, L.), and crab-grass (*Stenotaphrum Americanum*, Schr. = *S. glabrum* of Lefroy[2]), have 'anchored' the sand, so that it is no longer a menace. Sir Wyville Thomson writes of 'coral' sand in this account and elsewhere: as a matter of fact, there is no such thing as coral-sand in Bermuda; the present beaches are not indebted to coral for their materials, but to various marine molluscs, corallines, algæ, serpulæ, Foraminifera, the tests of echini, Crustacea, etc.; coral is generaliy conspicuously absent.

The material that constitutes the present shore sand is washed in from comparatively shallow depths, whereas coral lives at depths of "from 5 to 6 fathoms on the inner edge of the flats to the outer limits, the beginning of the broken ground, the corals extending to 8 or 10 fathoms on the southern faces of the flats".[3] He also says: "The Bermudian reef corals are, like the Bahama reefs, submerged, rarely come to the surface, and have not supplied any considerable part of the material which has gone to build up an extent of land either in the Bahamas or Bermudas." This, any field geologist would corroborate.

The marine mollusca that contribute to the present shell-sand of the recent beach are represented by the following genera: *Arca*, *Barbatia*, *Bulla*, *Callista*, *Cardium*, *Cerithium*, *Columbella*, *Conus*, *Cylichna*, *Cyphosoma*, *Cypræa*, *Dentalium*, *Diplodonta*, *Eulima*, *Fissurella*, *Glycimeris*, *Melampus*, *Murex*, *Nassa*, *Nerita*, *Olivella*, *Patella*, *Pecten*, *Rissoa*, *Spirula*, *Spondylus*, *Trivia*, *Vermetus*. There are probably many others, but these are in my own cabinet.[4]

It would extend these notes unduly if I were to describe the swamps, which, though not very extensive, are of great depth, and may go back to very early times, but as they have not been explored downwards there is but little known with sufficient exactness for any lengthy geological report. Suffice it to say that Governor Lefroy found the depth of the peat in Pembroke marsh in 1872 to be 42 feet.

IV. The Serpuline 'Atolls' or 'Boilers'.

The term here used refers to the round, or horseshoe, or S-shaped, or compound-shaped reef edges which occur on the south shore (Pl. XX, Fig. 2). "They are, perhaps, the most interesting structures in the Bermudas. They . . . constitute miniature atolls and barrier and fringing reefs, apparently formed by the growth of serpulæ. While serpulæ undoubtedly cover a great part of the

[1] *Voyage of the "Challenger"*, vol. i, p. 310, figs. 74–6.
[2] Lefroy, *Botany of Bermuda*, 1874.
[3] Agassiz, *A Visit to the Bermudas in 1894*, pp. 237, 243.
[4] Through the kindness of Miss Aimée Kempe, of Warwick parish.

surface of the structures, yet calcareous algæ, corallines, barnacles, mussels, and other invertebrates are found to be fully as abundant as the serpulæ, which, in many cases, play only a secondary part in the organic covering . . . Before my visit to the Bermudas, I accepted the explanation given by older writers of the mode of formation of the atolls, as due to the accelerated growth of serpulæ on the outer rim. I was therefore greatly surprised on hammering at some of these structures to find that the vertical walls were not built up, as is generally believed, of serpuline limestone, but were composed of æolian rock, and to discover that in many cases the elevated rim was protected by the hard ringing crust so characteristic of limestone exposed to the action of the sea, and, further, to find that the coating of serpulæ, algæ, corallines, and nullipores was quite superficial." Agassiz [1] gives good reason for believing that these miniature reefs are caused by the gouging action of the surf on æolian rock, submerged at high tide, but at other times elevated a foot or so above the water, on which the incessant play of the waves has a degrading effect. The growth of serpulæ, etc., protects the outer rim, and these interesting structures are the result.

The serpulæ are curiously more abundant on the south 'reefs' than on the north flats. There this phenomenon is not so well developed: the surface of the northern ledges are mainly protected by a small species of barnacle, clusters of *Mytilus*, encrusting nullipores, and a few small species of algæ.[2]

V. The Foraminifera.

I am indebted to Mr. Richard Holland for the following report on the Foraminifera which I have submitted to him:—

"Six packets of various kinds of materials were sent to me for examination, namely—

I. Coarse recent sand from Mermaid's Hole.
II. Fine recent sand from Long Bay.
III. Very fine fossil sand from near the Park, St. George's.
IV. Fine sand, probably from Shelly Bay.
V. } Fine sandy material collected from the insides of various land shells
VI. } from the Paget formation.

"*Specimen I.* This might fairly be described as a shelly gravel. It contains no fine material, and is, in fact, too coarse for the occurrence of Foraminiferal debris or even entire Foraminiferal shells. It consists largely of molluscan debris with coarse sponge spicules and other organic remains.

"*Specimen II* has a general resemblance to Specimen I, but it is much finer, and includes a great quantity of Foraminiferal debris, rolled and worn *Orbiculinæ* and *Orbitolites*, and numerous complete smaller shells.

"Both Specimen I and Specimen II are perfectly clean sands, with not the slightest admixture of mud, calcareous or other.

"*Specimen III* is a fine sand with a slight admixture of calcareous

[1] Agassiz, *A Visit to the Bermudas in 1894*, pp. 264–7, figs. 1–7. Also Nelson, op. cit., p. 116, figs. 11–13.

[2] Agassiz, op. cit., p. 264.

mud. It is full of Foraminifera, many of them in a very good state of preservation. The sand is described as fossil, but it is probably of late Post-Tertiary age. The shells are essentially similar to those from the recent beaches, and there is no trace of mineral infiltration.

"*Specimen IV* is said (but with some hesitation) to come from Shelly Bay, and I understand that it is thought to come from the recent beach. I doubt this. It is certainly different in character from Specimens I and II, and I am inclined to think that it is *washed* material from a deposit similar, but rather richer, to that from which Specimen III was taken. It is the best material of the six specimens for Foraminifera, and it is particularly rich in good specimens of *Orbiculinæ*. I should think it probable that similar material was in Carpenter's possession when he wrote the chapter on *Orbiculina* in the *Introduction to the Foraminifera*.[1]

"*Specimen V* and *Specimen VI* are somewhat similar in character to Specimen III, but considerably more muddy and with no perfect shells. There are abundant traces of Foraminifera, but all much decayed. The shell debris shows no trace of mineral infiltration, and the mud is apparently entirely calcareous.

"The material taken as a whole seems to me to represent a continuous series, that is to say, while Specimens I and II are clearly recent, the doubtful Specimen IV and the fossil Specimens III, V, and VI are of very late geological age and present no fundamental differences, beyond decay from weathering, from the recent material. The only noticeable distinction is that Specimen IV, which, however, I think has in all probability been washed, is richer in *Orbiculinæ* of large size than any of the other specimens.

"So far as the Foraminifera are concerned the material is remarkable for its great richness in fine specimens of *Orbiculina adunca* (Fichtel and Moll), in every stage of development and in wide variety of form. But Bermuda has long been known as an exceptionally good locality for that species, both in the recent and in the sub-fossil condition. Every variety of *O. adunca* figured either by Carpenter in his *Introduction to the Foraminifera*, or by Brady in the *Challenger* Report, is represented in this material, and the specimens are exceedingly abundant.

"As is usual in deposits very rich in examples of a particular species, this material does not furnish a wide variety of other genera and species. There are numerous specimens of Milioline forms, including *Biloculina ringens* (Lamarck), *Miliolina seminulum* (Linné), *M. pulchella* (d'Orbigny), *M. bicornis* (Walker & Jacob), and *M. reticulata* (d'Orb.). Fragments also of *Vertebralina* and *Articulina* have been met with. There are a few fragments of *Peneroplis*, numerous fragments of *Orbitolites*, and some young specimens of the genus in a good state of preservation. There are some good specimens of *Alveolina melo* (Fichtel & Moll), both recent and fossil; and some well-preserved examples of *Nonionina depressula* (Walker & Jacob) and *N. Boueana*, d'Orb. A very few small and obscure *Dentalinæ* have also been met with.

[1] Formerly in Dr. Henry Woodward's cabinet.

"The arenaceous forms are not well preserved. There is a considerable amount of debris, and some fairly good specimens of *Clavulina angularis*, d'Orb., have been found."

VI. Some Recent Evidence of Submergence.

(1) *Phosphorite Rock from Manhattan Shoal* (Pl. XXIII, Fig. 2).—In the Museum at Hamilton there is a large block of red rock from the Manhattan Shoal, probably a core from a hole made in blasting the rock for deepening the navigation channel in 1847. It came from a depth of 18 feet. If this were below O.D. it would be from 4 feet in the rock, which is probably the depth, more or less, of this interesting formation. Mr. L. L. Mowbray has kindly permitted me to sectionize the material and to have a petrological report inserted in this paper.

Mr. Russell F. Gwinnell, B.Sc., F.G.S., A.R.C.S., reports as follows:—

"This is a hard rock which does not effervesce on treatment with cold concentrated H Cl. Generally brown-red in colour, it appears in the hand-specimens to consist mainly of small spherical and ellipsoidal bodies together with a few subangular fragments, bound together by a cement which does not fill up the interspaces between the round bodies. There is no apparent striking difference in colour or hardness between any of the constituents of the rock (Pl. XXIII, Fig. 2).

"Under the microscope the round bodies are seen to be of various sizes, from a diameter of about 1·5 mm. down to perhaps 0·1 mm.; a great many are approximately 0·4 or 0·5 mm. in diameter. They show a certain amount of concentric zoning of colour, often with a lighter interior and darker border; otherwise there is no well-defined structure (as is frequently seen in oolitic and pisolitic grains), but the whole body contains numerous irregular fragments scattered promiscuously throughout. This structure is strongly suggestive of coprolites. The rounded bodies are non-pleochroic and isotropic. All the characters, so far, suggest the material as being phosphorite, the amorphous variety of calcium phosphate ('apatite' when crystalline) having been originally produced as coprolites, that is, the excrement of such animals as fishes or birds. For this reason, chemical tests for phosphorus were kindly made for me by Mr. T. Eastwood, A.R.C.S., and the presence of this element was clearly indicated. The rock also contains a few small subangular pieces of quartz and calcite.

"Encrusting the rounded bodies (which will now be spoken of as 'guano' or coprolites) is a thin layer of a transparent material, nearly colourless in thin section. This material also occurs apparently inside a coprolite, but this appearance may be due to the invagination of the surface of the coprolite. In polarized light this encrusting material is seen to be anisotropic, formed of fibres arranged normally to the surface which is encrusted. The birefringence is very low, but the refraction decidedly high. The fibres give straight extinction between crossed nicols, and a determination of the optical sign proves the material to be negative. These optical characters, together with the mode of occurrence, leave no room for doubt that this encrusting

mineral is staffelite, a fibrous encrusting crystalline variety of calcium phosphate. A comparison of this rock with other examples of phosphorite with encrusting staffelite shows a high degree of resemblance.

"Coprolitic phosphorite, being amorphous and variable in composition, has no definite specific gravity, but as crystalline apatite reaches up to 3·2, we may consider phosphorite to be perhaps 10 per cent. lower, or about 2·9. Taking the specific gravity of the rock in mass with a Walker's steelyard, a value of about 2·6 was obtained, but this was obviously much too low, owing to air imprisoned in the interstices. A piece of the rock was therefore broken up and the crushed fragments placed in a heavy liquid. By this method, using Klein's solution (cadmium borotungstate in water), the specific gravity was determined with some accuracy to be 2·91.

"The rock No. 1 may therefore be described as phosphoritic rock with staffelite. Its origin may perhaps be accounted for by the accumulation of the excrement of fishes or more probably of birds." [1]

In a second communication Mr. Gwinnell says that a confirmatory test for phosphorus in the rock had been performed and shows the abundant presence of phosphorus. He has thus proved the presence of phosphorus by both dry and wet chemical methods, as well as recognizing the phosphorus-bearing mineral by specific gravity and by a number of optical properties.

(2) *The Crystal Cave, near Bailey Bay.*—This cave has been opened to the public within the last two years. As it is lighted by electricity the dazzling beauty of the stalactites has not been spoiled by smoke. It was discovered by the persistent selling by boys for some time of stalactites of great purity and beauty but of unknown provenance. The source of their supply was at last found out. They used to enter down a natural sloping passage (now artificially closed) which had also been the entrance for the numerous birds which left their bones for the present race of naturalists to find and describe. Mr. L. L. Mowbray is to be congratulated on the discovery of so many avian skeletons and also of their feathers preserved in the stalactite. The determination of these remains is being steadily pursued, and geological science will soon be enriched by their accurate description and diagnosis.

The salt-water lake in the cave is called the 'Cahow' Lake, in honour of the bird, now extinct, which frequented the islands 300 years ago in great numbers, but was ruthlessly exterminated about 250 years since, being hunted in the night.[2]

[1] The second alternative seems to me to be the most feasible. It is difficult to conceive such a hard rock being formed under salt water from such materials. Such crystallization would more likely take place on land elevated above the sea-level, where crystallization could go on at the base of guano beds. Solid rock is not forming under the sea at the present day. Wherever the sea bottom is dredged the material is unconsolidated at all depths from 1 to 10 feet, and is mostly an impalpable mud containing numerous shells quite loose in the dredged material. (Verrill, op. cit., pp. 138 seqq.)

[2] Verrill, op. cit., p. 258, quoting a letter dated 1614, written by the Rev. Lewis Hughes. "Here is also plenty of sea-foules, at one time of the yeare, as about the middle of October, birds which we call Cahouse and

1. Deep cut, 'Khyber Pass,' Warwick Parish, Bermuda.
2. Pinnacles, æolian rock, St. George's, Bermuda.
3. Pinnacle in process of formation, Bailey Bay, Bermuda.

The Crystal Cave is now entered by stairs to about a depth of 90 feet, and then progress is made on floating pontoons. The water in this cave is some 12 to 20 feet deep; the lower parts are completely submerged at all times of the tide, for the water inside rises and falls with the tide outside, the average fall and rise of which is about 4 ft. 7 in.

There are three very large stalagmites as well as several smaller ones, but the larger ones challenge attention by their great size. The gangway passes quite close to the largest, which as nearly as we could judge is some 7 feet in diameter at the base, about half that at the summit, and at least 10 feet high. It is much larger than the 'Milne' stalagmite, now in the Edinburgh Museum, which was sawn off in 1819 by Admiral Sir David Milne from the cave near Tom Moore's Calabash-tree. This was 11 ft. 3 in. high, 25 inches in diameter, and weighed 3½ tons.[1] (The diameter at the apex was of course less.) The stalagmite at the Crystal Cave weighs at least 12 tons.

These huge masses of carbonate of lime were formed when the cave stood at a much higher level, since it would be quite impossible for them to form in their present position under sea-water. Moreover, there must have been a much greater rainfall than at present to have dissolved and scoured out this magnificent cave, and this points to a land surface at a higher level for the cooling and precipitation of aqueous vapour.

VII. The Grey Rock from the Deep Cut at Warwick (*vulgo* 'Khyber Pass'). (Pl. XXI, Fig. 1.)

This rock is the most puzzling of all the rocks from Bermuda. In the Museum at Hamilton is a small mass of hardened rock from

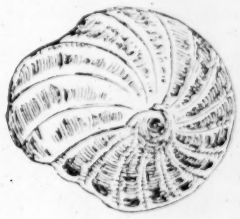


Fig. 5. *Poecroplis pertusus*, grey rock, 'Khyber Pass,' Warwick East, Bermuda. × 40 nat. size.

a depth of 32 feet in the Paget formation, found in blasting the road. This road has been deepened from time to time so as to make the gradient more easy for carts and horses.

Pimlicoes come in. The Cahouse continue til the beginning of June in great abundance, they are bigger bodied than a Pigeon and of a very good and firm flesh. They are taken with ease if one do but sit downe in a darke night and make a noise, there will more come to him than he will be able to kill: some have told me that they have taken twelve or fourteen dozen in an hower." (The names are onomatopœic, from the cries of the birds. The pimlico has been identified as the 'dusky' or Audubon's shearwater; *vide antea*.)

[1] Verrill, "The Bermuda Islands: Geology": Trans. Conn. Acad. Arts Sci., vol. xii. p. 85, note.

In one small piece which I also owe to Mr. L. L. Mowbray is a cast of *Peneroplis pertusus* (Fig. 5 text). The specimen from which the cast comes must have been quite unworn and perfect. The position is some 75 feet above O.D., and at a distance of about 580 yards from the present shore on the south side.

I append the petrological report of Mr. Russell F. Gwinnell :—

"This rock is seen in thin section to be composed of fragments of organisms (preserved in calcium carbonate) which are embedded in a dense grey-brown cement. The organic fragments reach up to about 0·8 mm. in greatest diameter. They are very varied in form, and it is impossible to identify many of them (Pl. XXIII, Fig. 1). Some may very likely be Bryozoa, others coral. A few pieces are definitely recognized as the calcareous alga *Lithothamnion*, which is a very well-known form on coral reefs.

"The dense cementing material is difficult to identify. It may be a calcareous mud, formed of comminuted organic fragments and possibly compacted by a certain amount of secondary recrystallization. If so, this recrystallization has not gone far. The comminution may be due to purely mechanical causes or the material may have passed through the body of some animal, thus being coprolitic. A minute fragment, which was not used in making the thin section, was therefore tested for phosphorus: owing to the small size of the fragment, the test was not decisive, but it is probable that this element was present. The curious colour of this cementing material in thin section and its apparently fragmental character would suggest a coprolitic origin.

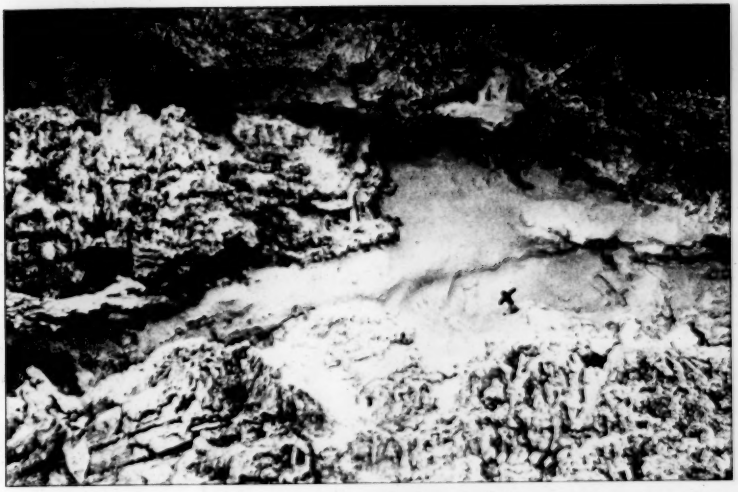
"Thus rock No. 2 is a clastic rock, made up of organic fragments (of which some are definitely recognized as coral-reef forms, and others may well be so), cemented together by a dense material. This cement probably consists largely of comminuted organic fragments, which have possibly been phosphatized (as well as comminuted) by coprolitic means."

The puzzle is how the perfect Foraminifer (Text-fig. 5) could have reached a spot so far from its native element and become embedded in what has become hard dense coprolitic rock.

The explanation perhaps is that the rock was formed in a spot to which sea birds resorted, and their deposit was calcified in later times gradually and slowly, the *Peneroplis* having been blown thither by the wind uninjured, since it could not have been ingested by any sea bird and remained in so perfect a condition as its cast shows it to have been. It is to be hoped that more of this type of rock may be discovered near the spot, for the rock at the Museum is evidently only a small fragment of a much larger mass.

The only other alternative is so improbable that it is only needful to mention it, namely, that the specimen is from a deep-sea mud, of which there are soundings from depths of 1,375 to 2,650[1] fathoms.

[1] Wyville Thomson (*Atlantic*, vol. i, p. 99) gives the depths at which such grey mud and ooze occur near the Bermudas: Station xxxi, S. 2,475 fathoms; Station xxxii, S. 2,250 f.; Station xxxiv, N. 1,375 f.; Station xxxvii, E. 2,650 f.; Station lv, N. 2,500 f.; Station lviii, E. 1,500 f. The respective



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1. Pot-holes in process of formation, St. David's Head, Bermuda.
2. Pseudo-palmetto stump, cliff, Hungry Bay, Bermuda.
3. Reticulated and honeycombed hard limestone, Bermuda.

This would account for the perfection of the Foraminifer, but not for the coprolitic nature of the principal material.

VIII. Some instructive Photographs.

(1) *The Carving Out of Pinnacles.*—One of the photographs which I took at 7 p.m. shows a pinnacle on the north shore near St. George's, probably in the Walsingham formation (Pl. XXI, Fig. 2). The hardening of the rock near the sea, by whatever agency it is effected, results in some remarkable structures. If the whole mass were to become indurated there would be merely a dense rock of more or less monotonous outline. But inasmuch as the shell-sand becomes more compacted into hard rock in some parts than in others, in consequence of percolation acting irregularly, there are often pockets of loose sand contained in harder rock. When the loose sand is washed or blown out, pinnacles are sometimes the result.

This is clearly seen in the second photograph (Pl. XXI, Fig. 3). The soft sand is being carved and etched out by the very agency that originally deposited it. The unconsolidated sand is seen as being cut out gradually by æolian action, and a pinnacle is in process of formation, like the finished pinnacle of the former photograph. The shell-sand here contains numerous land shells of the species *Pœcilozonites Bermudensis*, var. *zonatus*, Verrill, which can be seen in relief on the wind-cut surface. This natural arch is at Bailey Bay, also on the north shore. It belongs to the Paget Series (Pl. XXI, Fig. 3).

(2) *The Formation of 'Pot-holes'.*—The view is at St. David's Head, near the lifeboat station. In the upper part of the section is seen the wind-blown nature of the shell-sand formation (Walsingham Series). Lower down the action of the rain and spray has produced a honeycombed or reticulated appearance in the rock surface, which is pitted with small holes. On the face of the opposite rock is seen the process of formation of a 'pot-hole', by the revolving action of three stones which are swirled round and round by the impact of the waves during strong winds (Pl. XXII, Fig. 1).

(3) '*Pseudo-palmetto Stumps.*'—'Pot-holes' are considered by some to be the same as the 'pseudo-palmetto stumps'. The indurated sides of 'pot-holes' are supposed to become hard cylinders, and when weathered out to look like the stumps of trees. This may be so if it can be proved that they do weather out in this fashion, but it is quite as likely that they are drainage holes in the older Walsingham rocks; the calcitic material in solution, being deposited on the vertical sides of these watercourses, would cause the formation of these tubular pseudo-fossils from which the less dense external shell-sand has been denuded.

There are places where 'pot-holes' occur so thickly that they could not be the fossil remains of a grove of palmettos.[1] It is not their habit to grow so thickly together, and they prefer a peaty boggy soil, of which there is not the slightest indication in the structure of

distances from Bermuda of the first five are 53, 26, 18, 43, and 66 miles respectively. The distances are prohibitive of the second explanation, even if the enormous depths did not forbid.

[1] Agassiz, *A Visit to the Bermudas in 1894*, p. 269, pl. xxix.

the surrounding rock. Wyville Thomson[1] considers these pseudo-palmetto stems to have been formed on the floor of caves by the dropping of water charged with calcic material in solution. But these pseudo-palmetto 'fossils' are mostly hollow, while stalagmites are not. The pseudo-palmetto fossil figured is from the Walsingham rock on the east side of Hungry Bay (Pl. XXII, Fig. 2).

In conclusion, I would thank those in Bermuda whose names have been mentioned in the course of this paper, also Dr. Henry Woodward for editorial advice, Mr. Bullen Newton for access to Major Peile's collection at the British Museum (Nat. Hist.), Mr. Holland for examining and reporting on the Foraminifera, and Miss G. M. Woodward for preparing the illustrations.

EXPLANATION OF PLATES.

Plate XXI.

Fig. 1. Deep cut ('Khyber Pass'), Warwick parish, from a view published in Bermuda.
.. 2. Pinnacle in æolian rock, St. George's, north shore.
.. 3. Pinnacle in process of formation by æolian agency, Bailey Bay, north shore.

Plate XXII.

.. 1. 'Pot-holes' in process of formation, St. David's Head.
.. 2. 'Pseudo-palmetto stump,' cliff east side of Hungry Bay.
.. 3. Reticulated, honeycombed, hard limestone, showing effect of sea spray, rain, and air on exposed rock. In the centre of the rock is a pocket of soft shell-sandstone. Both the hard and the soft rock contain innumerable land shells of *P. Bermudensis*, var. *zonatus*, Verrill, and belong to the same series of Paget rocks. At 'x' a fine *Livona pica* was dug out by Mr. E. Morton Ingraham, of New Britain, Conn., U.S.A.

Plate XXIII.

.. 1. Grey rock from the 'Khyber Pass', Warwick, Bermuda. × 8·5.
.. 2. Phosphorite with Staffelite (Guano rock), Manhattan Shoal, near Paget Island, St. George's, Bermuda. × 10.

II.—On the Tuberculation of the Holectypoida.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

I. INTRODUCTION.

One of the most obvious contrasts between the Regular and Irregular Echinoids is in the character of their radioles, and of the tubercles on which the radioles are supported. Among the Regulares the size of the radioles is usually in inverse proportion to the number which rest on an individual plate of the test; and, to some extent, the same generalization applies to the Irregulares. There is, however, a differentiation of the radioles among the more typical Irregular groups, which results in a corresponding irregularity in size and disposition of the tubercles. Generally speaking, the radioles of the Regulars are stout and few, while those of the Irregulars are slender and numerous. While, in an *Echinus*, the largest and strongest of the radioles are ambital, or even superior

[1] *Atlantic*, vol. i, p. 330.

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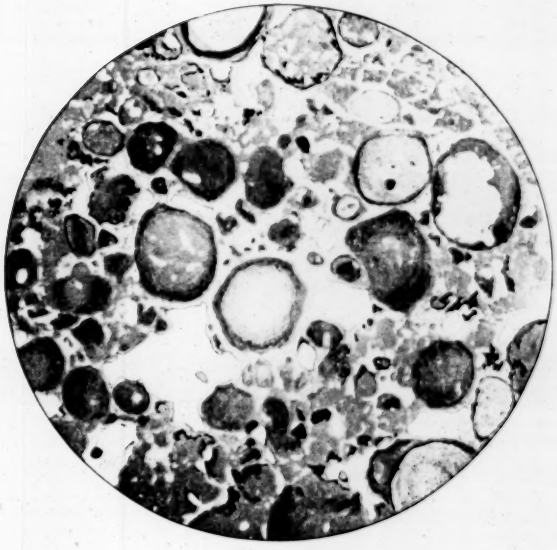

1. Grey rock from 'Khyber Pass', Warwick East, Bermuda. × 85.
2. Phosphorite with Staffelite, Manhattan Shoal, near Paget Island, Bermuda. × 10.

(adapical) in position, in an *Echinocardium* the most strongly developed are situated almost entirely on the inferior (adoral) surface.

These contrasts, in common with most of the others, between the two great groups of Echinoids, are, to a considerable extent, bridged over by the Holectypoida. In view of the very scanty evidence available for a study of the actual acanthology of the group, the proportions of the tubercles have to be regarded as furnishing an index of the character of the radioles. The investigation may be taken along two lines; the characters of the individual tubercles, and their changes in proportion and structure in different parts of the same test, and the changes in the order of distribution of the tubercles on the plates, which appear on a comparison of different species and genera.

The importance of the arrangement of the primary tubercles, as a guide to genetic sequence, has not received the recognition it deserves. Most authors, when figuring new species of Echinoids, give an enlarged drawing of one or more interambulacral plates to show this feature, but the meaning of it is rarely emphasized in the text, and often, owing to the not infrequent irregularities of growth in individual specimens, the figure becomes positively misleading. Almost the only occasion of which I am aware, when this character was exhaustively studied for systematic purposes, was in a paper by Saemann and Dollfuss in 1861 (Bul. Soc. géol. France, ser. II, vol. xix), where a distinction was diagnosed between *Pygaster gresslyi* and *P. laganoides* (*P. morrisi* being united to the latter species) on the evidence of the tuberculation. It is very doubtful whether the arrangement of the tubercles in the Spatangids, or even in the 'Cassidulids', could ever be used for the purpose of accurate diagnoses of species or even genera, its extreme complexity and consequent tendency to irregularity rendering a study of the interambulacra in these forms somewhat bewildering.

In the more complex Regular Echinoids, and in all the Holectypoids, the primary tubercles occur in regular vertical series in the interambulacra. These series appear with marked regularity until the ambitus is reached, after which they disappear in a corresponding order. There is always one row, approximately median in its position in the half-interradius, which persists from the apex to the peristome, and is commonly more prominent than the others. The other series of tubercles may be described as occupying the *interradial* or *adradial* tracts, according as they occur on one side or the other of this median series. The irregularities of development, which occur naturally, become more frequent as the complexity of the tuberculation becomes more marked. For the most part the diagrams here given are generalizations, which omit the numerous individual peculiarities.

In the Holectypoida the tuberculation shows a progressive complexity of arrangement when it is traced from the Jurassic to the Cretaceous representatives. As Saemann and Dollfuss showed in the paper already referred to, the value of this feature as a specific index depends very largely upon the age of the individual—a question often difficult to solve in the case of fossil forms. Far more evidence

than I have yet been able to procure is necessary before the tuberculation can be made a reliable specific character. There is, however, in this branch of study, more possibility than in most other aspects of the Echinoidea, of tracing recapitulation during individual development. When A. Agassiz (in the *Revision of the Echini*) and others have shown that in, for example, a post-larval *Echinolampas*, each interambulacral plate bears a solitary tubercle (so passing through a '*Cidaris*'-stage'), it is at least probable that a study of the tuberculation of young stages in the less highly specialized Holectypoida will afford a useful guide to a determination of relationship. In this paper the feature is treated from a generic rather than a specific standpoint. After a description of characteristic types has been given, some general deductions as to the phylogenetic meaning of the various characters will be indicated.

II. THE TUBERCULATION IN CHARACTERISTIC SPECIES.

1. Pygaster semisulcatus (Phill.).

(*a*) *The Structure of the Tubercles.*[1] (Fig. 1, A.)

The primary tubercles are small on the adapical surface, prominent, but still small, on the ambitus, and but little larger adorally. The greater breadth of the scrobicules in the last-named region makes the tubercles there appear considerably larger than they are in reality.

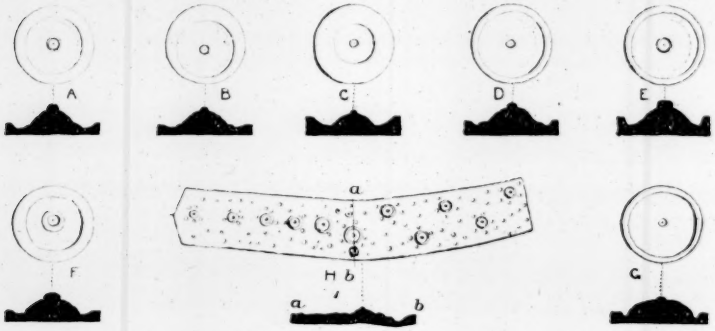

Fig. 1. Diagram showing the comparative structure of the tubercles (in plan and section) in the Holectypoida. A, *Pygaster semisulcatus*; B, *P. umbrella*; C, *P. 'morrisi'*; D, *Holectypus hemisphæricus*; E, *Anorthopygus orbicularis*; F, *Discoïdea cylindrica*; G, *Conulus albogalerus*; H, plate 17 from an *Holectypus depressus* (and section along line *a*–*b*), showing socketed tubercle. [The tubercles represented (except in H) are all from the ambitus.]

Adapically the tubercles are smaller on the interradial than on the adradial tracts. The *scrobicule* is circular, very shallow in adapical tubercles, more deeply excavate in those of the adoral surface, where the scrobicules of adjacent tubercles are often confluent (or separated by a low, smooth ridge) transversely, but never vertically. The *scrobicular ring* is very irregular and indistinct. The *basal terrace* is

[1] The terminology employed is that standardized by Bather in his monograph on the Triassic Echinoderms of Bakony, 1909, p. 61.

well marked. The *boss* rises in an S-curve from the vertical edge of the terrace. It is always in the centre of the scrobicule. The *parapet* is but slightly raised above the *platform*, and both are smooth. The *mamelon* is small in proportion to the size of the boss, but almost covers the platform. It is roughly spherical, and has a small, circular *foramen*.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, A.)

As in all the Holectypoida, the plate next the apical system has only one tubercle, subcentral in position. In *Pygaster* the first four or five plates may retain this primitive character. The tubercles of this first series occur on every plate from apex to peristome, and, from the second plate downwards, are all towards the adoral margin of the plate in position, though never far from the centre. On the interradial tract there appear, in a persistent sequence as the transverse diameter of the plates increases, new tubercles, which develop into horizontal as well as vertical lines. Their position is midway between the adapical and adoral margins of the plates, a feature which distinguishes them clearly from the excentric main series. On the adradial tract there is a corresponding growth of fresh tubercles, but these develop into a different order. The first formed adradial tubercle is quite near to the adapical margin, while the second is equally near to the adoral. This zigzag horizontal arrangement is maintained, however many vertical rows of adradials may be developed. A study of the diagram will render the arrangement more intelligible than a detailed description. The disappearance of the rows of tubercles, after the ambitus is passed, is definitely in the inverse order of their appearance, on both the adradial and interradial tracts.

This method of arrangement is the simplest and most typical of those found among the Holectypoida. It results in an appearance as of broken horizontal lines of tubercles in the middles of the interambulacra, and of massed arrays of oblique series along the adradial regions. The tendency to a degeneration, or rather a lack of development, of the large radioles in the adapical interradial tracts, which is so prominent a feature in such genera of Regular Echinoids as *Cœlopleurus*, is thus seen to be present in *Pygaster*.

2. Pygaster umbrella, auct.

(*a*) *The Structure of the Tubercles.* (Fig. 1, B.)

The primary tubercles are small and inconspicuous on the adapical surface, except those round the periproct. Adorally they are considerably larger, and increase steadily in size almost to the margin of the peristome. The *scrobicule* is practically flush with the test-surface adapically, and but little more excavate below. The *scrobicular ring* is even less marked than in *P. semisulcatus*. The *basal terrace* and *boss* are similar to those in that species, but smaller in proportion, even adorally. The most significant feature of distinction between the tubercles of the two species is that in *P. umbrella* the boss is not in the centre of the scrobicule (in adoral tubercles), but tends towards the adoral side of the centre. The excentricity is not great, but is a persistent feature, and one which suggests a comparison with the extreme excentricity of the bosses on some parts of the tests of

Spatangids. The *platform* and *mamelon* are like those of *P. semisulcatus*, save for their smaller proportions to the rest of the tubercle.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, B.)

Though fewer in number and less regular in size, the tubercles in *P. umbrella* follow the same plan of arrangement as do those of *P. semisulcatus*. On the zigzag series of the adradial tracts, a curious, but apparently constant, irregularity in the order of the appearance of the vertical rows occurs. After the proximal series of adapically situated tubercles has appeared, the next to develop is series *three*, also adapical. Not for a plate or two do these two series become separated by the delayed appearance of the adorally placed series *two*. The same anomaly occurs in the growth of the next pair, and the retention of the principle of inverse order for their disappearance on the adoral surface results in a similar irregularity of the series in that region.

The incoming of irregularity in the tuberculation seems somewhat significant in view of the fact that the crowding of the tubercles is less marked in this species than in any others of the genus. It is not surprising to find trifling disorder appearing when the tubercles are minute and numerous, but in this case there seems no other reason for its presence but some fundamental tendency in evolution. *Pileus pileus*, which is also a Corallian form, and closely allied to *Pygaster*, seems to show a similar tendency, although I have not been able to examine any specimens which show the tuberculation clearly. *Pygaster macrocyphus*, from the Kimmeridge Clay, undoubtedly has an exactly similar irregularity, and it may be that these late *Pygasters*, with the periproct passing farther and farther from the apex, are showing in the tuberculation that plasticity of development which often accompanies or precedes the differentiation of new types. It would, however, be premature to discuss here the possible outcome of this reawakening of evolution in the genus.

3. Pygaster 'morrisi',[1] Wright. (Fig. 1, C.)

The group to which *P. laganoides*, *P. gresslyi*, and *P. truncatus* belong is one which was separated from the true *Pygasters* by Pomel (*Classification méthodique*, 1883) under the generic or sub-generic name of *Macropygus*. Previously both Desor (*Synopsis*) and Cotteau (*Echinides de la Sarthe*) had expressed the opinion that the group, while admittedly possessing peculiar features, did not merit generic distinction. Little support or comment has been given to Pomel's resuscitation of Desor's disowned name *Macropygus*, but the considerable differences from the typical forms that the three species referred to above exhibit might, perhaps, warrant its retention in a sub-generic sense. In no particular is this difference more clearly shown than in the character of the tuberculation. Instead of the shallow, broad scrobicules of *P. semisulcatus*, these parts in *P.* (*Macropygus*) '*morrisi*' are narrow and deep, so deep that the top of the mamelon is often but little above the

[1] I do not wish here to express an opinion as to the distinction or identity between this species and *P. laganoides*, Agass., but use Wright's name to indicate that the specimens I have examined are all from British localities.

general level of the test. The difference in size between the tubercles of the adapical and adoral surfaces is hardly appreciable, and they are closely packed over the whole test.

The principle of their arrangement is, however, exactly similar to that in *P. semisulcatus*.

4. Holectypus hemisphæricus (Desor).

(*a*) *The Structure of the Tubercles.* (Fig. 1, D.)

There is a very marked disparity in size between the tubercles of the adapical and those of the adoral surface in this species, the former being less than half the dimension of the latter.

The *scrobicule* is circular and moderately excavate, but the *scrobicular ring* is poorly developed. The *basal terrace* is even more abruptly marked off from the floor of the scrobicule than in *Pygaster*. Its diameter is but little less than that of the scrobicular circle, so that the *boss*, which is fairly high, almost fills the scrobicule. This feature is more noticeable adapically than adorally, since in the latter region the area of the scrobicules is increased rather more than that of the bosses. The *mamelon* is minute and perforated, but, in spite of its small size, almost entirely covers the narrow, uncrenelated *platform*.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, C.)

The general plan of the tuberculation is the same as that observed in *Pygaster semisulcatus*, except that, in spite of the considerably smaller size of an adult *H. hemisphæricus*, it normally bears more vertical series of tubercles per plate than the larger *Pygaster*. The specimen on which the diagram is chiefly founded shows a feature, present in only a few of those that I have examined, which seems significant. On the adradial tract of pl. 14 (marked with a cross in the figure), it will be noticed that, in place of the two adapically and adorally situated tubercles which go to the formation of the zigzag arrangement, *three* distinct tubercles are present. Trifling though this irregularity appears, it would seem (especially in view of its occurrence in several specimens), to have some phylogenetic significance. The triple arrangement of the tubercles becomes the rule in *Conulus*, as will be seen later, and here, in the Inferior Oolite, there seems to be a precocious tendency in some specimens of *H. hemisphæricus* to assume characters which do not become general until the Middle Cretaceous.

5. Holectypus depressus (Leske).

There seem to be two very distinct types of *Holectypus* passing under this name, one from the Inferior and Great Oolite, and the other from the Cornbrash. At present, however, I do not feel justified in distinguishing the two forms by name, especially as this paper is not systematic in purpose. The Inferior Oolite specimens are usually small, and their tuberculation is practically identical with that of *H. hemisphæricus*. There is one very notable feature which distinguishes both *H. depressus* from the last-named species, this being the relative number of plates above and below the ambitus. A comparison of the two figures (2, C and D) will make the contrast clear. In *H. depressus*, as soon as the ambitus is passed, the plates of

the adoral surface rapidly become large, and therefore few in number, whereas they were peculiarly narrow on the adapical surface.

The specimens of *H. depressus* from which Fig. 2, D was constructed were all the large, Cornbrash forms. It will be seen that the arrangement of the tubercles is of the normal *Pygaster* type. There are, however, some features in the details of their structure which are worthy of more detailed description. (See Fig. 1, H.)

The proportionately greater size of the tubercles of the adoral surface, and especially of their scrobicules, when compared with those of the adapical region of the test, is more marked in this species than in *H. hemisphæricus*, chiefly on account of the much larger area occupied by each adoral plate. Apart from the extreme and *Pygaster*-like size of the adoral scrobicules, the details of tubercle-structure are alike in the two species. But on the adapical surface, on the plates which are about midway between the apex and the ambitus (pls. 8–17 in the diagram), a curious feature, unique as far as any other species I have examined are concerned, makes its appearance.

In the line of the central row of primaries, and between the main tubercle and the adoral margin of the plate, there occurs a small tubercle sunk in a deep socket. The details of the scrobicule and boss of this supernumerary tubercle seem identical in every way with those of the main series, but, owing to the obliquity of the floor of the socket, the tubercle points slantingly in an adoral direction. At first sight the socket looks like the open pit of a *sphæridium*, but, apart from the fact that it is nowhere near the peristome, the presence in it of a perfectly normal tubercle precludes the possibility of its having this function. The other, and more feasible, suggestion which its appearance provokes, is a comparison with the sunken, oblique major tubercles of the interpetalous regions of some of the more highly specialized Spatangids. The details of the relations and structure of this peculiar feature will be understood more clearly by an examination of Fig. 1, H, than from verbal description. I have not found any trace of a corresponding feature in the *H. depressus* from the Inferior Oolite.

In addition to this anomalous series of additional tubercles, it will be noticed, on reference to Fig. 2, D, that in the same region of the test some of the granules rise to the importance of actual tubercles. These extra tubercles, indistinguishable structurally (except in point of size) from the ordinary serial primaries, are always developed on or near to the central line of the plate, and to the adapical side of the main tubercle. The presence of these hypertrophied secondaries is again a precocious feature. In *Discoïdea* and *Conulus* they are typical and numerous, but the Cornbrash *H. depressus* is the only Oolitic form in which I have observed them.

6. Discoïdea cylindrica (Lam.).

(*a*) *The Structure of the Tubercles.* (Fig. 1, F.)

The disparity in size between the tubercles of the adapical and adoral surfaces reaches its extreme (for the Holectypoida) in *Discoïdea*. Not only are those of the upper surface small and inconspicuous in themselves, but a considerable increase in the number and size of the

granules helps to give this part of the test an almost uniformly granular appearance. In the smaller species of the genus, such as *D. subucula*, this feature is carried so far that, except in very well-preserved specimens, it is practically impossible to distinguish between the tubercles and the granules. In *D. cylindrica* the distinction is rather more apparent. The main row of first-formed tubercles is considerably more clearly marked than the lateral series on the upper surface, and is situated on a prominence of the test which often becomes a carina passing vertically down the median line of each interambulacral plate. On the adoral surface the tubercles are much larger, and are all of approximately equal size. As will be seen by reference to the figure, the structure of an individual tubercle is very like that in the previously described genus, save that the basal terrace is peculiarly prominent and the platform very broad. It should be noted, however, that the adapically situated tubercles have practically no scrobicule, a fact which renders their separation from the granules additionally difficult.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, F.)

The diagram for this species is an actual copy of the tuberculation of one specimen—a beautifully preserved example of the *forma depressa*—in the collection of Mr. G. E. Dibley, F.G.S. It was found in the zone of *Holaster subglobosus* at Burham, Kent. It will be seen that the usual order of horizontal rows on the interradial, and of oblique rows on the adradial, tracts obtains in this species. There is a marked increase in number (as well as in size) of the tubercles at and below the ambitus, but these very rapidly disappear when traced towards the mouth, so that the adoral surface is but sparsely tuberculate over most of its area. In addition to the increase in size and number of the normal tubercles at the ambitus, many of the granules (which are usually disposed in more or less transverse lines in this genus) become exalted to the rank of tubercles, giving an appearance of double horizontal rows of tubercles on each plate in this region. Often these supernumeraries are quite as large as the original tubercles, although, for the sake of clearness, they are represented as dots in the diagram.

7. Anorthopygus orbicularis (Grateloup).

(*a*) *The Structure of the Tubercles.* (Fig. 1, E.)

The most striking contract between the tuberculation in this genus and that in those already described lies in the fact that the tubercles of the adapical surface are hardly distinguishable from those of the adoral surface in point of size. In this the genus recalls the sub-genus *Macropygus*, but the equality in size is yet further noticeable than in that Upper Jurassic series. The *scrobicules* are rather more deeply excavate than in *Holectypus*, and the *mamelons* considerably larger in proportion, but otherwise there are no important differences in structure.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, E.)

For a long time, even after I had become familiar with the order of the tuberculation in *Conulus*, I was unable to satisfy myself as to the

manner of its arrangement in *Anorthopygus*. Not only were the sutures between the plates obscure in all the specimens available, but there seemed no trace of a central median series passing vertically

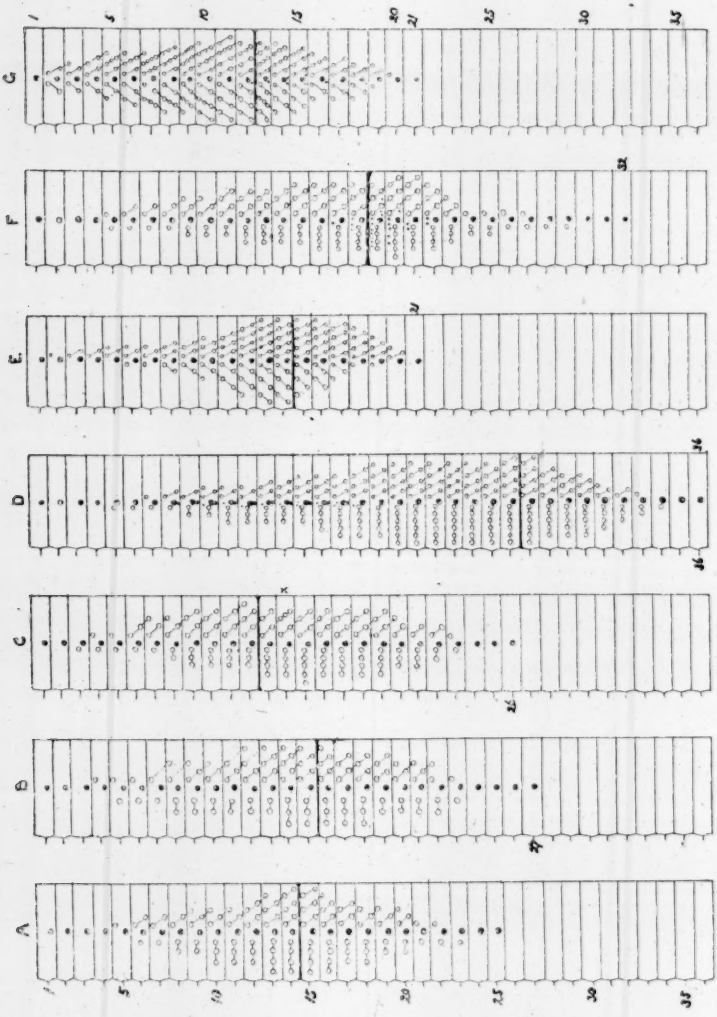

FIG. 2. Diagram showing the comparative arrangement of the tubercles (in a half-interradius) in the Holectypoida. A, *Pygaster semisulcatus*; B, *P. umbrella*; C, *Holectypus hemisphæricus*; D, *H. depressus*; E, *Anorthopygus orbicularis*; F, *Discoidea cylindrica*; G, *Conulus albogalerus*. [The thick line represents the ambitus. The relative proportions of the tubercles are not indicated.]

from apex to peristome. It was only after persistently recurrent examination, and the drafting of frequent, often varying, diagrams of each specimen, that the system became manifest. One reason for its obscurity lies in the fact that the tubercles of the median series are placed very near to the adoral margins of the plates, and so lose the prominence which comes of isolation. The other, and most important, reason, is the order of position of the tubercles on the interradial tracts of the plates. An examination of one interambulacral plate of this species shows the tubercles to be arranged in two alternating horizontal lines, reaching from the adradial to the interradial sutures, and so closely packed that there is little room for granules between them. This is due to the presence of oblique pairs of tubercles on the *interradial*, as well as on the adradial, tracts; the adoral situation of the central series bringing those tubercles into a horizontal line with the lower members of the zigzag couples. The importance of this arrangement lies in the fact that the interradial tract, instead of being relatively poor in tubercles, becomes almost as thickly covered with them as the adradial portion. This is in striking contrast to the features of all the previously described forms, but affords a link with the genus next to be described.

8. Conulus albogalerus, Leske.

(*a*) *The Structure of the Tubercles.* (Fig. 1, G.)

In this genus the difference in the proportionate diameter of the tubercles of the upper and lower portions of the test is not so pronounced as in *Discoïdea*, but more so than in *Anorthopygus*. The retention of a well-marked scrobicule in the adapically situated tubercles, and the reduction of the 'granules' to the nature of pits, renders the upper ones very obvious, in spite of their usually low relief. The *scrobicule* is circular, quite deeply excavate in adoral tubercles, and well-marked, though shallow, in those of the adapical surface. The *boss* rises almost directly from the scrobicular circle with a sharply convex outline. On the adoral surface the boss rarely exceeds in height the depth of the scrobicule—adapically it usually projects slightly above the ring. The *platform* is broad, without a marked parapet, and quite smooth. The mamelon is small and has a deep central *foramen*.

(*b*) *The Arrangement of the Tubercles.* (Fig. 2, G.)

Although considerably more complex in order of sequence, the tubercle series in *Conulus* are far more readily traceable than in *Anorthopygus*. This is due to the more nearly central position (in a vertical sense) of the tubercles of the main series. Although these are often smaller than the lateral tubercles, and never larger, their isolation and position render them useful indices of the boundary between the adradial and interradial tracts. Except in very young forms of this species (and in moderately small specimens of *C. subrotundus*) there are rarely more than two plates at the apex which bear only one tubercle. There is thus a marked acceleration in the rate of appearance of the tubercles—even more than in the case of *Anorthopygus*. As in that genus, the interradial series of tubercles

are oblique, as well as the adradial ones. But while in *Anorthopygus* there are never more than the necessary two tubercles in the oblique line, in *Conulus* three, or even four, may appear. The couple nearest the median series is, however, usually only dual in its composition. There is a greater tendency for this multiplication on the adradial than on the interradial tracts, and the oblique series are more closely packed in the former area. A few scattered supernumerary tubercles always appear near the ambitus, but these are not so numerous, nor so largely developed, as in *Discoïdea*.

III. THE TREND OF EVOLUTION IN THE TUBERCULATION.

In the descriptions of characteristic types just completed, there are two features which stand out pre-eminently as fixed and uniform. These are, the smooth, unerenelated character of the summits of the tubercles, and their occurrence in regular vertical series which appear and disappear towards the two poles of the test in inverse order, leaving one central and persistent series which alone occupies some of the latest formed (adapical) and most reduced (peristomial) inter-ambulacral plates. The universality of this unituberculate character of some of the plates throughout the group is an indication of its primitive position among the Irregular Echinoids, a belief which is confirmed by the fact that the number of plates which retain this character is less in the Cretaceous than in the Jurassic species. With the possible exception of the Echinonidæ and some of the genera allied to *Caratomus*, it would seem that, in adult specimens, no plates with a single tubercle remain.

But against these two persistent features may be placed two of equal importance, but exhibiting a progressive character when traced through the group. These are the relative proportions of the tubercles of the upper and lower surfaces of the test, and the distribution and number of the tubercles on any individual ambulacral plate. In these features the main lines of change seem to be maintained with considerable regularity when regarded stratigraphically. In the *Pygasters*, and especially in those from the Inferior Oolite, the distinction in size between the tubercles of the two surfaces s hardly appreciable. There is a greater density of packing adorally, but little actual difference in the diameter of either scrobicule or boss. In the later (Upper Jurassic) *Pygasters* this similarity is less pronounced, the adoral tubercles showing a marked increase in size, both actual and relative. In *Holectypus* the change is carried further. The number of adorally situated tubercles decreases, but their size increases in an almost inverse proportion in *H. depressus*, while the adapical tubercles are small and often imperfectly developed. In *Discoïdea* the tendency reaches its maximum, a few series of large tubercles existing adorally, while adapically the tubercles and granules can hardly be distinguished from one another. *Conulus*, and still more *Anorthopygus*, seem not to respond to the tendency in so marked a degree, but, as these genera do not appear to have any direct genetic relationship with *Discoïdea*, but rather to be an offshoot from Upper Jurassic *Holectypi* or even *Pygasters*, this fact does not interfere with the general principle.

In the peculiar Cenomanian form, *Anorthopygus*, the tuberculation has reverted (or at least shows a likeness) to the original *Pygaster*-feature of equality all over the test. This archaic trait seems to accord well with the retention of the periproct on the adapical surface. *Conulus* follows with a fresh tendency to irregularity, more of relief than of diameter, in the development of the tubercles. It may be noted that this slight contrast in size is also met with in the very closely allied genus *Pyrina*, the character of whose tuberculation seems, in most respects, intermediate between that of *Anorthopygus* and *Conulus*.

In the details of tubercle-structure the change would appear to have been from the concavo-convex outline of a boss standing freely in a large scrobicule, to the purely convex outline of a boss rising almost directly from the scrobicular circle. Coupled with this change is a lessening of the relative size of the mamelon, and a shallowing or even partial atrophy of the scrobicule.

When the arrangement of the tubercles is considered, a far more striking progression becomes apparent. In a young *Pygaster semisulcatus* many of the interambulacral plates support but one tubercle each, while there are usually three or four, often more, plates at each pole, which, even in adults, remain unituberculate. The arrangement of the additional tubercles is different on the two sides of the median row, being horizontal interradially and oblique adradially, the adradial tract of the area thus becoming comparatively densely tuberculate.

In *Holectypus* the number of additional tubercle series increases, but always on the same plan of arrangement as in *Pygaster*, and leaving the interradial tracts relatively bare of tubercles, a feature betokening the persistence of a tendency most strongly marked in the Regular Echinoids. *Discoidea* carries on the sequence, but amplifies and elaborates it by the addition of many extra tubercles at and near the ambitus.

This group of forms, which is typified by the three genera *Pygaster*, *Holectypus*, and *Discoidea*, may be taken as forming, broadly speaking, a genetic series.

In the case of *Anorthopygus* and *Conulus* a great difference is found. *Anorthopygus*, although resembling a *Pygaster* in many of its features, shows not merely an increase in the number of tubercles on each plate, but a uniformity of distribution of those tubercles by the change from the horizontal to the oblique order in the disposition of the interradial series. In addition to this, an acceleration in the growth of the tubercles appears, very few plates, whether adapical or adoral, retaining the primitive unituberculate habit. In *Conulus* we seem to have the same tendency to reduce the relative size of the adapical tubercles, which appeared in the *Pygaster–Discoidea* series, working on an *Anorthopygus*-like arrangement of the tubercles. It seems impossible to maintain a natural separation between the 'Echinonidæ' and 'Echinoconidæ' in the feature of tuberculation, as in most other details of structure.

IV. SUMMARY.

It may be taken that the general tendency of the evolution of surface ornament (and therefore of the radioles) in the Holectypoida

was a dual one. The large tubercles become gradually restricted to the adoral surface, and often reduced in number, while the actual density of the tuberculation increases. This increase is attained, either by a simple multiplication of the normal vertical series, as in *Discoïdea* (this being sometimes associated with the transformation of granules to tubercles at the ambitus), or by a more uniform distribution of those series over the area of the plates, and the frequent substitution of two tubercles in the place of one, as in *Conulus*. Both these types of change lead away from the primitive, 'Regular' condition of tuberculation, and trend towards the Clypeastroid and Cassidulid arrangement.

In view of the fact that, in almost every detail of comparative anatomy, the Holectypoida show a retarded evolution, it may be considered that the sequence of changes reviewed above actually represents, in a dilatory and extended manner, the process which, at one or more stages of geological history, produced a uniform and packed tuberculation from the solitary series of large tubercles which characterize the Cidaridæ.

Finally, I wish to express my thanks to Messrs. G. E. Dibley, Ll. Treacher, and T. H. Withers for the loan or gift of specimens which were invaluable in the construction of the diagrams.

III.—What is Laterite?

By L. Leigh Fermor, A.R.S.M., D.Sc., F.G.S., Geological Survey of India.[1]

Contents.

I. Introduction.
II. The Previous Discussion.
III. The Nomenclature of Laterite.
IV. The Application of the term Bauxite.
V. The Lateritic Earths of British Guiana.
VI. Summary.

I. Introduction.

FEW natural mineral products have aroused more general interest or been more provocative of discussion amongst geologists than that superficial rock-formation so typical of the tropics known as laterite. This material excites interest not only because of its chemical composition, but also on account of its wide distribution. It has been recorded, for instance, from tropical South America (e.g. the Guianas and Brazil), Central Africa (e.g. Guinea and East Africa), the Seychelles, India, the Malay Peninsula, the East Indies, and Western Australia. Many papers have been published dealing with its distribution, composition, and also its origin, to explain which many hypotheses have been invented.

Owing to the large number of occurrences of manganese-ore found in India in association with lateritic rocks,[2] I had, when working at

[1] Published with the permission of the Director, Geological Survey of India.

[2] To prevent this casual allusion to the subject of Indian manganese-ores giving rise to one of those misconceptions which, once formed, are so difficult to eradicate, I must state at once that the lateritic manganese-ores are, as a rule, of small importance compared with those of the Archæan areas.

the Indian manganese-ore deposits, many chances of striking a field acquaintance with laterite. Consequently, following the fashion of theorizing about laterite, I took the opportunity, in my memoir on the Manganese-Ore Deposits of India,[1] of expressing my own views, at the same time summarizing some of the theories previously advanced, especially with reference to Indian laterite. Concerning the origin of this rock I advanced the views (1) that rocks of more than one origin were included under the term *laterite*, (2) that in discussing the origin of this rock geologists had not always recognized this fact, and (3) that consequently the divergent theories put forward were in some cases invented to explain dissimilar occurrences. Further, the opinion was expressed that no profit could be derived from the further discussion of this question unless each author discussed a specific occurrence, of which a detailed description was at the same time given, so that no confusion should arise in the future. An actual case was then discussed, showing that two parts of one deposit of laterite have probably been formed in two different ways—one by the alteration of rock in situ, and the other by chemical deposition from a body of water.

In this chapter (p. 370) the term *laterite* was defined implicitly, but not explicitly, in the following passage:—

"This rock consists essentially of a mixture of hydrated oxides of iron and alumina, with often a considerable percentage of titania,"

this definition being intended to apply to all varieties of laterite formed in situ, but not to such varieties of the so-called low-level laterites as are of detrital origin, nor to any detrital or reconstructed varieties of high-level laterite; *it is only to laterites formed in situ that the present paper applies*, except where otherwise stated.

I may quote also another passage (p. 379), which does not advance any theory as to the origin of laterite, but states what I believe to be the *result* of lateritization of a rock. The passage is as follows:—

"It is also generally recognized that the formation of this type of laterite involves the disappearance, probably in solution, of the silica, lime, magnesia, and alkalies, of the original rock, with the concentration of the oxides of aluminium, iron, titanium, and sometimes manganese, to form laterite."

In holding these views I was, of course, but repeating Professor Bauer's[2] and Sir Thomas Holland's[3] ideas on the composition of laterite, and consequently on the definition as to what is laterite that naturally follows.

During 1909 and 1910, however, current geological literature was enlivened by two discussions about laterite: one of them, in the pages of this Magazine, referring to the use of the words *laterite* and *bauxite*; and the other relating to a paper entitled "The Origin of Laterite" read before the Institution of Mining and Metallurgy by Mr. J. Morrow Campbell.[4] As many of the participants in these discussions do not seem to have given sufficient attention to the views of Indian geologists on a rock which is, after all, primarily an Indian

[1] Mem. Geol. Surv. India, xxxvii, ch. xix, pp. 370–89, 1909.
[2] Bauer, *Neues Jahrb. für Min.*, etc., ii, p. 163, 1898.
[3] Holland, GEOL. MAG., Dec. IV, Vol. X, pp. 59–69, 1903.
[4] Trans. Inst. Min. Met., xix, pp. 432–57, 1910.

rock, it seems to me desirable to develop what I think are the general ideas of Indian geologists on this question.

I propose to deal in this communication only with the *nomenclature of laterite* and to avoid as far as possible any discussion on its origin, and consequently I will first summarize the discussion that has taken place in the pages of this Magazine.

II. The Previous Discussion.

On pp. 100–3 of his work *The Geology of the Goldfields of British Guiana* (1908) Professor J. B. Harrison describes under the name of laterite certain residuary earths of which analyses are given, and which are obviously not true laterites in the sense outlined above. This work is reviewed in vol. vii of the Bulletin of the Imperial Institute, 1909, pp. 133, 134, a protest, in my opinion both justifiable and necessary, being raised by the reviewer against Professor Harrison's use of the word *laterite*. The reviewer says—

"The exact sense in which it is used is not defined, but the weathering products included under it appear to be in all cases ferruginous and siliceous clays. . . . These can scarcely be laterites in the modern sense of the word, which should be restricted to that product of weathering in hot moist climates which contains free aluminium hydroxide. The analyses of laterites proper usually show excess of alumina with silica as a subordinate constituent, though a considerable amount of iron and titanium oxides may be present."

Mr. J. B. Scrivenor[1] objects to the reviewer's attempt to restrict the meaning of the word *laterite*, regarding it as impracticable, and putting forward the interests of engineers as follows:—

"The reason of this is that the term 'laterite' has been used, in the Malay Peninsula at least, for many years by a large body of engineers for what are essentially masses of iron oxide replacing portions of weathered rock and filling fissures in such rock near the surface. This (Malayan) laterite is most abundant in weathered schists, and is largely used for public works. Small quantities of aluminium hydroxide may or may not be present in these masses of ironstone, but that question is of no immediate importance to the engineer, who values the stone for its hardness."

The material referred to in this passage is probably identical with the rock I have designated *lateritoid*[2] amongst the Indian lateritic rocks in order to indicate its resemblance to, and yet difference from, the more typical laterites (*infra*).

Mr. Scrivenor's letter leads to a reply from Mr. T. Crook,[3] of the Imperial Institute, who quotes Buchanan's original definition, and, remarking that the author of the term clearly distinguished iron-ore from the laterite in which it occurred, objects to the application of the term to *iron-ores* and *ferruginous clays*. Incidentally Mr Crook remarks—

"It is a complex product, essentially characterized by the presence of free hydrated alumina, but usually containing also notable amounts of titanium and iron oxides, whilst free silica is generally present, and hydrated silicate of aluminium is not necessarily absent. The amount of iron oxide is very variable, but when it becomes excessive it usually separates out in the form of concretionary iron ore."

[1] Geol. Mag., 1909, p. 431.
[2] Mem. Geol. Surv. India, xxxvii, p. 381, 1909, and *infra*.
[3] Op. cit., p. 524.

In a second letter[1] Mr. Scrivenor, in order to illustrate the confusion surrounding the use of the term *laterite*, calls attention to the opinions of Dr. Maclaren[2] and Mr. Mennell[3] that an alternation of wet and dry seasons is necessary for the formation of laterite, and produces statistics of rainfall at Malacca to show that at that place there is no such alternation of seasons. And, whilst he admits that the rock called *laterite* by engineers in the Federated Malay States is *ironstone* deposited in weathered rocks, Mr. Scrivenor maintains that there exists in the State of Malacca an occurrence of rock that agrees with Buchanan's definition of laterite. He concludes by conjoining the doubt raised by Mr. Kilroe,[4] as to the necessity of tropical conditions for the formation of laterite, with his own deduction that an alternation of wet and dry seasons is unnecessary.

In another letter Mr. Scrivenor[5] replies to Mr. Crook to the effect that the essential point of Buchanan's original definition of laterite is that laterite sets when exposed to the air. Hence, if Crook's dictum that laterite must contain free aluminium hydroxides is to be accepted, he must prove that the setting of laterite is due to the dehydration of aluminium hydroxides and not to that of hydroxides of iron, as has been previously held. Mr. Scrivenor thinks that we can dispense with the term *laterite* altogether, as having now too loose a meaning, and use the term *bauxite* instead, for, according to passages he quotes from Holland and H. and F. J. Warth, laterite and bauxite are essentially similar.

Dr. J. W. Evans[6] now comes to Mr. Crook's assistance to combat Mr. Scrivenor's suggestion referred to above, and maintains that in India the term *laterite* is still applied, both in scientific, technical, and popular language, in the sense in which it was used by Buchanan over a century ago. He gives recent literature on the subject, and summarizes matters in the following clear words:—

"As a result of the work that has been done it is found that the chemical composition of laterite varies within wide limits according to the nature of the original rock, so that it is not necessarily the same as that of bauxite. One feature, however, remains constant, the small amount of combined silica in proportion to the alumina present, and it is in this respect that laterites differ from clays, which also occur as tropical decomposition products and are sometimes incorrectly described as laterites. If, again, the amount of ferric oxide is large, it is apt to form ferruginous concretions, which are commonly referred to as *lateritic iron ore*."

Mr. Crook[7] next returns to the attack and objects very strongly to Mr. Scrivenor's proposed misuse of the term *bauxite*, and denies that this word is yet available for petrographical use, maintaining that the non-existence of the compound $Al_2O_3 2H_2O$ as a mineral must first be definitely established.

Mr. Scrivenor,[8] in a further communication, replying to Dr. Evans, reiterates his point that the term *laterite* must not be held to imply the presence of free aluminium hydroxides in quantity; he states that

[1] Geol. Mag., 1909 p. 574.
[2] Op. cit., 1906, p. 546.
[3] Op. cit., 1909, p. 350.
[4] Op. cit., 1908, p. 539.
[5] Op. cit., 1910, p. 139.
[6] Op. cit., p. 189.
[7] Op. cit., 1910, p. 234.
[8] Op. cit., p. 336.

he finds free aluminium hydroxide in weathered granite, in kaolin, and in slate, as well as in all the Malayan laterites.

Dr. Evans[1] then allows the permissibility of using the term *bauxite* as a commercial mineral term to apply to laterites exceptionally poor in silica and in iron, provided it is understood that it is not to be employed as a rock name.

Mr. Scrivenor[2] replies to Mr. Crook in the same part of this issue, and quotes Lacroix as saying with regard to *bauxite*, "C'est en réalité une véritable roche." At the same time Mr. Scrivenor quotes an experiment in which he obtained over 13 per cent of alumina from decomposed granite, which should therefore, according to the definition advocated by Crook and Evans, be designated laterite, although no one in the Malay States regards it as such.

The correspondence in the pages of this Magazine ends here, for the time at least; but Professor Harrison, apparently under the stimulus of the original Imperial Institute review and of the subsequent discussion, from which he has quietly held aloof, has meanwhile had carried out a series of chemical analyses of the residual earths of British Guiana, which he describes in conjunction with Mr. K. D. Reid, in a paper extending into three numbers of this Magazine.[3] This paper is one of considerable importance, as it furnishes valuable material for the discussion of the composition of tropical surface decomposition products. Incidentally I may remark that it seems in my opinion to justify in full the objection advanced in the Imperial Institute review to Professor Harrison's use of the word *laterite*, for not more than a very few of the rocks and soils analysed are worthy of this name, such terms as *lateritic soil* and *clay* being more suitable.

III. The Nomenclature of Laterite.

In the sequel I propose to discuss Professor Harrison's paper at greater length, but it is first necessary for me to advance my own views on the subject. During recent years I have had field experience in various parts of the peninsula of many occurrences and varieties of Indian laterite. I have examined rocks that I regard as true *laterites* in the Balaghat and Jabalpur districts of the Central Provinces, in the Belgaum and Satara districts of the Bombay Presidency, in the Portuguese territory of Goa, and in the Sandur Hills in Madras; whilst of the type of lateritic rock I call *lateritoid* I have seen occurrences in the Singhbum district of Bengal, in Jabalpur, in Goa, in the Sandur Hills, and in the districts of Chitaldrug, Kadur, Shimoga, and Tumkur in Mysore; and, finally, I have examined the *lithomargic decomposition products* with a little laterite of the Nilgiri Hills. The consideration of these occurrences and of the specimens obtained therefrom, and also the work, published and unpublished, of such of my colleagues as have had extensive experience of laterite, particularly that of Sir Thomas Holland and Messrs. Hayden and Middlemiss, have led to very definite ideas as

[1] Geol. Mag., 1910, p. 382. [2] Op. cit., p. 384.
[3] 1910, pp. 439–52, 488–95, 553–62.

to which materials should, and which should not, be designated by the term *laterite*.

Difference between Laterite and Clay.—In the discussion summarized above three points are taken into consideration. Mr. Crook lays stress on the presence of free aluminium hydroxide, Mr. Scrivenor on the suitability of the rock for building purposes, whilst Dr. Evans lays stress on the small amount of combined silica in proportion to the amount of alumina present. In Dr. Evans' view lies the key to the question, I think. One should not decide whether a given rock is laterite on the basis of the presence or absence of alumina in quantity, but on the presence or absence of any considerable proportion of combined silica. Combined silica means the presence of kaolin or lithomarge, and the larger the amount of such material the closer does the rock approach a clay in composition. Now clays[1] are to be regarded as the end products resulting from one mode of superficial decomposition of rocks, and laterites as the end products of another totally distinct mode of decomposition. When a rock breaks down into a *clay* hydrated aluminium silicate is to be regarded as the pure end product, all oxides being removed in solution. When a rock is converted into *laterite*, on the other hand, the reverse holds; aluminium and other silicates are decomposed, and the silica is removed in solution, presumably in the colloidal form, whilst the oxides of iron, aluminium, titanium, and manganese, which were relatively soluble under the clay-forming conditions, are relatively insoluble under laterite-forming conditions. The oxides of calcium, magnesium, sodium, and potassium are apparently soluble under both sets of conditions. I do not propose to advance here any reasons to account for these two diverse modes of surface alteration of rocks, nor to say anything about the conditions, whether climatic or organic, that bring them about, but to deal only with the results of such changes. *Pure clay*, then, is hydrated aluminium silicate, whilst *pure laterite*[2] is a mixture of one or more, or all, of the oxides of iron, aluminium, titanium, and manganese, more or less hydrated, which I refer to in this paper as the lateritic constituents.[3] Manganese oxide is a somewhat exceptional constituent, and when present usually

[1] i.e. clays formed in situ, as distinguished from those deposited as aqueous sediments.

[2] F. W. Clarke holds similar views, as may be judged from the following quotation from his *Data of Geochemistry*, pp. 417–18 (1908): "Whatever its derivation may be, whether from rocks in place or as a transported sediment, *true laterite* [my italics] is essentially a mixture of ferric hydroxide, aluminium hydroxide, and free silica in varying proportions. To laterite in situ this statement applies very closely; detrital laterite is usually contaminated by admixtures of clay. Just as in the formation of kaolin, the process of laterization may be complete or partial, the typical product appears only when the alteration of the parent rock has gone to the end. Then the silicates seem to be completely broken down, whereas in kaolinization a stable, hydrous silicate remains." Mr. J. M. Campbell's definition (loc. cit., p. 437) is also similar; he mentions manganese, titanium, and phosphorus, in addition to the constituents named by Clarke.

[3] Other related oxides, such as Cr_2O_3, have been found in laterite, and are to be regarded as true lateritic constituents. See Mem. Geol. Surv. India, xxxvii, p. 378, and *infra* of this paper.

segregates into masses of comparatively rich manganese-ore, as a rule either psilomelane or pyrolusite.[1]

Typical Laterite.—We may accept, then, that *true laterite* (or *laterite proper*) is a hydrated mixture of oxides of aluminium, iron, and titanium, of extremely variable composition, and showing every gradation from ferruginous laterite almost free from alumina to aluminous laterite almost free from iron. Such laterites are often sufficiently pure to be termed respectively iron-ore and aluminium-ore, which seem, at least in some cases, to be the result of segregative tendencies acting on a more homogeneous form of laterite, doubtless under the influence of percolating water. When pure enough to be used as aluminium-ore the laterite is usually known as *bauxite*.[2]

As examples of typical laterites, reference should be made to the analyses given in two papers by Sir Thomas Holland[3] and Dr. W. Dunstan[4] respectively, although it should be noted that the samples represent the paler and more aluminous varieties, as they were taken with a view of testing the Indian laterites as a source of aluminium: in order to give a thoroughly sound idea of the composition of Indian laterites, it would be necessary to select for analysis another series of samples illustrating the ferruginous varieties. The consequence is that the analyses referred to all show high percentages of alumina, ranging from 31·37 per cent to 67·88 per cent, and it may be the consideration of this series of analyses that has led the mineralogists at the Imperial Institute to lay such stress on the essential presence of alumina in laterite. The amount of ferric oxide present in these samples ranges from 0·44 per cent to 40·18 per cent, but samples could easily be selected running much higher in this constituent.[5] The titania ranges from 0·04 per cent to 13·76 per cent, the combined water from 16·81 per cent to 33·74 per cent, and the silica from 0·05 per cent to 19·32 per cent. Apart from three samples showing 10·75 per cent, 14·58 per cent, and 19·32 per cent SiO_2, however, the amount of silica is never more than 4·68 per cent, and in all but five cases does not even reach 3 per cent.

Quartzose Laterite.—Accepting the definition of pure laterite given earlier, it is evident that if a lateritic rock be markedly siliceous, it will need special scrutiny and consideration before it can be admitted as a laterite. The silica may be present in two principal forms, namely, as *quartz*, either residual from the original rock, or secondary, and as *lithomarge* or kaolinite. If present as quartz, then

[1] The Indian manganiferous laterites have been discussed elsewhere (Mem. Geol. Surv. Ind., xxxvii, pp. 380–9), and they need not enter further into the discussion here, although they are probably of greater importance and wider distribution than is generally recognized.

[2] I use this word in a petrographical sense, concerning which see Section IV of this paper, *infra*.

[3] "The Occurrence of Bauxite in India": Rec. Geol. Surv. Ind., xxxii, pp. 178–80, 1905.

[4] "Report on Laterites from the Central Provinces": ibid., xxxvii, pp. 215, 216, 1909.

[5] The third group of analyses by H. and F. J. Warth shows, however, three true laterites containing 47 per cent to 56 per cent of Fe_2O_3, with 33 per cent to 26 per cent of Al_2O_3. See *infra*.

the rock is evidently a *quartzose laterite*, which would graduate with increase in the amount of quartz into a *lateritic sand* or *sandstone*. Such a quartzose laterite might result from the action of lateritizing processes on a rock containing free quartz, such as granite or gneiss, the original quartz being then one of the insoluble constituents. If, however, the quartz is of secondary origin, as in some of the so-called laterites of Professor Harrison, then it is obvious that the lateritizing processes have not acted normally, for this quartz should have been removed in solution on the breaking up of the silicate containing it. In fact, its presence indicates that the process by which the original rock has been altered cannot be accurately described as a lateritic one and the resultant rock as laterite, in the sense of p. 460. In any case, such a rock should be regarded as but imperfectly-formed laterite, requiring a qualifying adjective, such as *siliceous*, before the word *laterite*.

Lithomargic Laterite.—If the silica is present in the combined form, it indicates the presence of kaolin or lithomarge, and consequently that the process of lateritization of the rock has, again, not been pushed to a finish, and that this rock also is an imperfectly-formed laterite, requiring a descriptive adjective, such as *lithomargic*. With any large quantity of combined silica present, calculation would show that there was a larger amount of lithomarge than of free oxides and hydroxides, and the rock would then be correctly designated a *lateritic lithomarge*.[1]

Pisolitic and Oolitic Rocks.—Amongst laterites and the related rocks pisolitic and oolitic forms are moderately common. The *pisolitic* and *oolitic* bauxites are true *laterites*, as also are some of the pisolitic iron-ores. But the *pisolitic* and *oolitic* manganese-ores at present known are *lateritoids*,[2] and they are, it is interesting to note, also the most aluminous of the aluminous lateritoid ores (see analyses Nos. 9, 10, 14, on p. 1188, loc. cit., of ores from Kumsi manganese mine in Mysore, showing 12 to 18 per cent of Al_2O_3). Whilst many of the concretionary iron-ores are true laterites, certain deposits of pisolitic limonite, such as those forming part of the laterite formation[3] near Katni in the Jabalpur district,[4] or such as the pisolitic limonite cementing the bauxite conglomerate of Yeruli in the Satara district,[5] may have been deposited chemically from bodies of water, on the analogy of the Swedish lake ores. Such lateritic deposits, in cases where there is a considerable degree of probability, might suitably be termed *lake laterite*. Under this term would also be included any laterites formed by chemical deposition in bogs after the manner of bog iron-ores. By admixture of the iron hydroxides, at the time of deposition, with mechanically deposited sand and clay, *siliceous lake laterites* would be formed, and if the amount of siliceous material were excessive the

[1] An analogous expression is *bauxitic clay* used by T. L. Watson in his account of the "Bauxite Deposits in Georgia", Bull. No. 11, Geol. Surv. Georgia, p. 52, 1904.

[2] Mem. G.S.I., xxxvii, p. 381, 1909; and *infra*.

[3] See *infra* for the use of the term *laterite* in a stratigraphical sense.

[4] Mallet, Rec. G.S.I., xvi, p. 103, 1883.

[5] Mem. G.S.I., xxxvii, p. 375.

rock would be related to the detrital laterites referred to in the next paragraph. Compared to the true laterites, the lateritoids, and the detrital laterites, however, the lake laterites are probably of small importance in India.[1]

(*To be continued.*)

IV.—On the Relation of the Glacial Drift to the Raised Beach near Porth Clais, St. Davids.

By Arthur L. Leach, F.G.S.

DURING a recent examination (August, 1911) of the glacial drifts in the neighbourhood of St. Davids, I have noticed some glaciated surfaces on boulders of the raised beach in a section on the coast near Porth Clais, where the relation of the glacial Boulder-clay to the raised beach is so clearly shown that (pending a fuller description of these deposits) the importance of the section seems to justify a preliminary notice.

The raised beach of the Gower Peninsula has been described by Mr. R. H. Tiddeman,[2] who obtained definite proof that the beach was pre-Glacial in the sense that it always lay below the glacial drift in that district. The deposits associated with the raised beach are grouped by Dr. A. Strahan[3] into a 'Raised Beach Series' composed of three distinct members. The following brief description of this series, as it is displayed in Gower, is taken from a paper

[1] I must point out here the logical sequence of the adoption of this term *lake laterite*. If one is to apply the term to pisolitic iron-ores that have been deposited by chemical precipitation from a body of water, and are, in addition, associated with bodies of typical laterite, it is difficult to avoid its extension to include those deposits of iron-ore, manganese-ore, and bauxite that have been formed in an identical manner, but are not associated with lateritic rocks. All the deposits classed as *bog iron-ores* and *lake ores* in textbooks on ore-deposits could then be called *lake laterites*, and also the *sedimentary manganese-ore deposits*. The lake iron-ores of Sweden, the bog iron-ores of various parts of Northern Europe, the manganese deposits of the Caucasus, and perhaps the iron-ores and bauxites of Antrim, must then all be classed as *lake laterites of various ages*. Further than this, if my theory of the origin of the manganese-ore deposits of the gondite series of the Central Province is correct (loc. cit., pp. 308–19, 365), they are to be regarded as in part (the *primary ores*) the product of metamorphism of a series of manganese-oxide sediments, chemically deposited in lake basins, and interlaminated with mechanically deposited sands and clays, the whole series representing a metamorphosed Caucasus (as has been noticed by De Launay in his recent work *La Géologie et les Richesses, Minérales de l'Asie*, p. 698, 1911). These Indian deposits are therefore *metamorphosed lake laterites*. However, I do not wish to give this extended meaning to the term, but insert this footnote merely to draw attention to the real significance of the existence of the lake laterites, if any such can be proved to exist. There is to me nothing objectionable in this term *lake laterite*, nor in its possible wide extension as outlined above, if fellow-geologists think it desirable. This possibility merely serves to point out the inherent chemical relationship between the typical laterites and many deposits of iron, manganese, and aluminium ores all over the world, which, whilst differing from true laterites in mode of occurrence and formation, are yet related to them through the lake laterites as defined in the body of this paper.

[2] Geol. Mag., Dec. IV, Vol. VII, 1900, p. 441.

[3] *The Country around Swansea* (Mem. Geol. Surv., 1907).

by Dr. Strahan on the geology of South Wales[1] in the Jubilee volume of the Geologists' Association.

"1. The highest member, or head, is a talus of angular fragments of limestone, obviously derived from the neighbouring cliffs, and containing no other rocks.

"2. Under this and mingling with it is a foxy-red sand, very variable in thickness, and containing an occasional snail-shell. This is evidently a blown sand.

"3. The lowest member is a layer of well-rounded pebbles of limestone, crowded with shells of recent species. . . ."

Dr. Strahan gives a list of these shells, and states that the shingle rests on a water-worn platform about 10 to 15 feet above the present level of the shore (or about 25 feet above Ordnance Datum), and that the head and the shingle are always firmly cemented by carbonate of lime. The proof of the pre-Glacial age of this series of deposits depends on Mr. Tiddeman's observations at several points on the Gower coast, where glacial deposits were found frequently to rest upon but never to underlie the raised beach deposits.

In South Pembrokeshire I have observed the 'platform' and its associated deposits at several points, but although the shingle, blown sand, and head always occupy the same relative positions as in Gower, the three members are seldom well displayed in any one section, and in no case has a glacial deposit yet been observed clearly resting upon the raised beach series. Mr. E. L. Dixon, who has mapped the raised beach in this district, remarks that at Bullum's Bay (Caldey) "the glacial deposit appears to overlie the raised beach, though the exposure is obscure, and the evidence of superposition is not so conclusive as in Gower".[2] Again, in the Milford Haven district the platform has nowhere been found in clear association with glacial deposits.[3]

Near Porth Clais in North-West Pembrokeshire, the stratigraphical relation between the raised beach and the glacial deposit is perfectly clear and conclusive. It is of interest to note that the evidence is to be found in the immediate vicinity of a section of the raised beach and head, figured by Prestwich in his great paper on "The Raised Beaches and Rubble Drift or 'Head'".[4] The sketch for the figure must have been taken from a point very close to the place where the glaciated surfaces are now exposed.

Prestwich mentions two raised beach sections, one "a short distance west of Porth Claus [Clais] Harbour", the other "half a mile W. of Porth Claus [Clais] Harbour". The first is illustrated by a figure which shows merely head resting on "Beach consisting of subangular fragments of Cambrian and pre-Cambrian Rocks, granite, veinstones, porphyry, white quartz pebbles, and a few flint pebbles". The second exposure, which was pointed out to Prestwich by Dr. Hicks, is described simply as "Beach 8 feet thick and covered by 15 feet of Head". One of these exposures, probably the second, must be

[1] See *Geology in the Field*, 1910, pp. 851–2.
[2] *Summary of Progress for 1905* (Mem. Geol. Surv.), p. 70.
[3] E. L. Dixon, *Summary of Progress for 1906* (Mem. Geol. Surv.), p. 63.
[4] Quart. Journ. Geol. Soc., vol. xlviii, 1902, p. 293.

identical with that described by me, but Prestwich drew no distinction between the head and the glacial drift.

About a quarter of a mile south-west of the little harbour of Porth Clais, near St. Davids, a mass of glacial drift forms a well-marked terrace, roughly semicircular in outline and convex towards the sea. In the low cliff or steep bank on the seaward margin of this terrace, which overlooks an inlet named on the 6 inch map Ogof golchfa, the glacial drift is seen resting in part on the solid rock and in part overlapping upon the raised beach (see Figure). From the western end a level rock-platform, about 15 feet above high-tide level, extends almost horizontally for about 50 yards across Lower Cambrian shales and sandstones, and then, rising slightly, passes over an igneous dyke (only a few feet wide) which has been planed down almost to the general level of the platform. A few yards further to the east a huge dyke fully 40 feet wide intersects the Cambrian shales, and the cleanly cut platform ends. Upon the platform rest many large well-worn boulders (closely resembling the beautifully ovoid boulders of the raised beach at Whitesand Bay, St. Davids) embedded

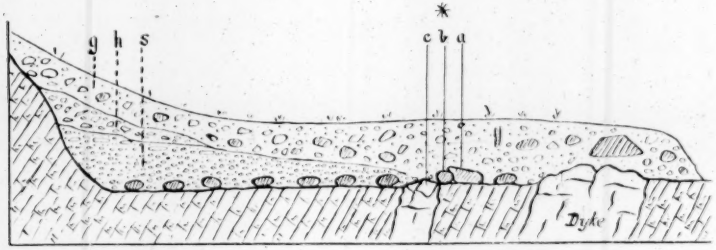

Diagram section of the Raised Beach and Boulder-clay near Port Clais, St. Davids. *g*, glacial deposit (Boulder-clay); *h*, head; *s*, stratified shingle and boulders of the raised beach; *a*, *b*, striated boulders of the raised beach; *c*, striated rock-surface.

in concreted beach shingle composed largely of flattish ovoid pebbles of various igneous rocks. The shingle, which is about 10 feet thick at its western end, contains many partly worn blocks of Cambrian shale and pebbles of sandstone, but igneous pebbles predominate, especially in its lower part, and the whole deposit, except the non-local boulders and pebbles, appears to be an old pebble beach such as might accumulate about high-tide level at the foot of cliffs composed of shales and sandstones with igneous intrusions. Upon the shingle lies head a few feet thick composed of angular debris from the rocks above. These two deposits are referable to the shingle and head of the Gower Raised Beach Series: the intermediate blown sand of Gower is not here represented. Over the head, and to some extent cutting into and mingling with it, lies a drift deposit (containing boulders), which I consider to be glacial and separable from the head, and to be directly continuous with Boulder-clay which some yards further east ploughs quite through the raised beach deposits and comes to rest on the solid rock. Although the western end of the section is inaccessible, it

can be closely inspected across a fault-chasm a few yards wide, and the point of greatest interest (indicated by * in the diagram) where the glacial deposit rests on striated boulders is easily accessible. Here (see Figure) several boulders of the raised beach remain firmly cemented to the platform, but most of the shingle has been swept away, and the boulders are covered by yellowish clayey drift. The boulder (*a*) is a 'beach' boulder of greenish igneous rock (probably local), and its upper surface is smoothed, polished, and covered with well-marked striations, of which a few run irregularly, but by far the greater number run uniformly slightly west of a N.W. by S.E. line. Before my visit this striated surface was hidden by soil,[1] and its remarkable freshness is due to this protective covering. The boulder (*b*), an almost spherical mass of Cambrian purple sandstone, lies next to (*a*) and is also a raised beach boulder, but it has been long exposed to the weather and the glacial striations have almost disappeared. The block (*c*) is not a beach boulder, but a piece of the igneous dyke which here forms the platform of the raised beach. It has one smooth water-worn surface covered by striations, now partly obliterated by weathering. These boulders lie at the margin of the preserved portion of the raised beach. To the west, under the head and glacial drift, boulders and shingle extend continuously for more than 50 yards, but to the east there is nothing but Boulder-clay.

The glacial character of the deposit superposed on the raised beach is well-marked. It is an unstratified gravelly Boulder-clay packed with blocks and pebbles of Cambrian purple sandstone in great abundance, boulders and pebbles of local igneous rocks such as the pre-Cambrian granophyre (Dimetian), and the later norites and diabases of the St. Davids Head intrusive rocks, with flint pebbles and other rocks probably not of local origin. It contains well-striated pebbles, and one huge diabase boulder (weighing some tons) which projects conspicuously upon the seaward face of the drift is at least a mile from the nearest exposure of any similar intrusive rock. Since this deposit rests in part on a striated surface and contains striated stones and erratic boulders its glacial origin is clear.

The succession may now be compared with that on the Gower coast[2]—

Gower.		Porth Clais.
g. Upper or Post-Glacial Head.		*g*. [Not clearly represented.]
f. Glacial Beds.		*f*. Glacial Boulder-clay.
e. Lower Head.	Raised	*e*. Lower Head.
d. Blown Sand.	Beach	*d*. [Not present.]
c. Raised Beach Shingle.	Series.	*c*. Raised Beach Shingle.
b. Raised Beach Platform.		*b*. Raised Beach Platform.
a. Present Beach.		*a*. Present Beach.

I have recently found in this district a representative of the post-Glacial head, which will be described on another occasion. The agreement in general level of the raised beach in the two cases is very close, and differences such as the absence of shells and of

[1] The soil has been replaced upon the glaciated surface and covered by a large slab of rock. The point * is 20 yards west of the large angular boulder indicated in the diagram.

[2] See Mr. R. H. Tiddeman's figure reproduced in *Geology in the Field*, p. 852.

blown sand, the presence of abundant igneous pebbles, and the looser character of the shingle and head at Porth Clais as compared with Gower are due to local conditions. In Gower the Raised Beach Series accumulated on a limestone platform, bordered by a sandy shore, which subsequently yielded the blown sand, and overhung by limestone cliffs whence the angular debris or head was derived. Carbonate of lime was therefore abundantly present to supply the calcareous cement by which the shingle and head are firmly concreted. Near Porth Clais, on the other hand, where the rock-platform was cut in non-calcareous shales (penetrated by igneous intrusions), and shelved rapidly into fairly deep water, neither the shingle nor the head contained any appreciable amount of calcareous material, and these members are but loosely compacted. They were, therefore, readily broken up when the Boulder-clay passed over them, and, in fact, the head is only clearly preserved under the lee of the steep cliff on the west; elsewhere so much glacial material has become mixed with it that the two are not separable. From the evidence given above the raised beach near Porth Clais, in respect to its elevation, constituent members, and relation to the glacial beds appears to correspond with that of Gower, and is similarly pre-Glacial in the sense that it underlies the lowest visible glacial deposit. But the mode of transport of the large igneous boulders, which occur as erratics in the raised beach both here and in South Pembrokeshire, is a problem requiring further consideration, and if the solution be found in the hypothesis that they were transported by drifting boulder-bearing ice, then the formation of the raised beach must be associated with a climate sufficiently cold to permit large masses of shore-ice to form around the beach boulders, and to drift several miles southward along the coast. The glaciated boulders described in this paper were not striated by shore-ice, which admittedly can in Arctic regions[1] striate stones and the rock-platform beneath. The definite and uniform direction of the striations is against this view, and shows that they were caused by land-ice moving in from the W.N.W. (approximately), and moreover no striations can be observed on beach boulders which are not directly overlapped by the Boulder-clay.

Summary.

1. The raised beach near Porth Clais consists of shingle and large wave-worn boulders resting on a rock-platform, and overlain by angular head or rubble of local rocks.

2. Glacial drift (Boulder-clay) overlies the head at the western end of the section, and towards the east has ploughed into the raised beach and rests on the solid rock. Some of the boulders of the raised beach and a small piece of the rock-platform are definitely striated under the Glacial drift.

3. The raised beach is pre-Glacial in the sense that it underlies the Glacial deposit.

4. The raised beach contains non-local boulders which may have been transported by drifting shore-ice.

[1] Colonel H. W. Fielden, Quart. Journ. Geol. Soc., vol. xxxiv, p. 556, 1878.

V.—The Correct Technical Name for the 'Dragon-tree' of the Kentish Rag.

By F. H. Knowlton, M.S., Ph.D., United States Geological Survey, Washington, D.A., U.S.A.

WHAT curious fossil organism, long known as the 'Dragon-tree', has been a puzzle to palæobotanists for almost three-quarters of a century. Bandied about among various monocotyledonous genera, then thought to be possibly related to the Cycads, and finally given a non-committal name that was without implication of kinship, though placed among the Cycads, it has at last, through the admirable research of Dr. M. C. Stopes,[1] been definitely allocated among the Conifers, and even among the higher members of that group. Dr. Stopes is certainly to be congratulated for having worked out its affinities in such a conclusive and convincing manner. It is to be regretted, however, that the scientific name she has finally adopted for the 'Dragon-tree' is not the one that is likely to meet the requirements of nomenclatorial permanency. The nomenclature of systematic palæobotany does not differ essentially from that of living plants, and must abide by the same rules.

The nomenclatorial history of the 'Dragon-tree' is briefly as follows: The first and most remarkable example was discovered in 1839 by W. H. Bensted,[2] and by him presented to the British Museum, where König gave it the manuscript name *Dracæna Benstedi*, apparently written on the specimen itself. This name was taken up by Morris[3] and by Mantell,[4] but it appears to have been first described and figured by Mackie[5] in 1862. In 1868 Carruthers[6] expressed the opinion that these stems were "more like those of a *Pandanus* than a *Dracæna*", but he did not change the name, nor did Gardner[7] in 1886 when he opined that they might belong to the Cycads. Apparently the status remained as above outlined until 1896, when Professor Seward[8] instituted for their reception the new genus *Benstedtia*, which he later tentatively placed among the Cycads. Seward described his new genus fully, but did not directly associate it with a species, though by citation its type was *Dracæna Benstedii*, König.

In 1900 Professor Fliche,[9] of Nancy, described under the new generic name *Coniferocaulon* certain casts of stems from the French Lower Cretaceous, which Seward[10] says "are, I believe, identical with those referred to *Benstedtia*". This generic identity of the French and English specimens is confirmed by Dr. Stopes, who, though calling the English stems *Benstedtia* throughout her paper, reaches the conclusion in the final paragraph that "Our plant, then,

[1] Geol. Mag., N.S., Dec. V, Vol. VIII, pp. 55–9, 1911.
[2] See his account, *Geologist*, vol. v, p. 336, 1862.
[3] *Cat. Brit. Fossils*, 1st ed., 1843, p. 7.
[4] *Petrifactions and their Teachings*, 1851, p. 49.
[5] *Geologist*, vol. v, pp. 401–4, pl. xxii, 1862.
[6] Geol. Mag., Vol. V, p. 154, footnote, 1868.
[7] Ibid. (3), Vol. III, p. 201, 1886.
[8] *Annals of Botany*, vol. x, p. 219, 1896.
[9] Bull. Soc. Sci., Nancy, (2), vol. xvi, p. 16, 1900.
[10] *Annals S. African Museum*, vol. iv, p. 35, 1903.

the *Dracæna Benstedii* of König, the *Benstedtia* sp. of Seward, is best designated by the name *Coniferocaulon Benstedii*".

The rules of nomenclature will not permit this combination, for if *Coniferocaulon* is congeneric with *Benstedtia*, it is antedated by four years and becomes a synonym of the latter. If these are not congeneric, then the type of *Benstedtia* cannot be taken from it, and the result becomes the same. Recapitulated, the correct name for the English 'Dragon-tree', together with its synonymy, stands as follows:—

BENSTEDTIA BENSTEDI (König), n.comb.

1896. *Benstedtia*, Seward, *Ann. Bot.*, vol. x, p. 219 [type *Dracæna Benstedi*, König].
1900. *Coniferocaulon*, Fliche, Bull. Soc. Sci., Nancy, (2), vol. xvi, p. 16.
1843. *Dracæna Benstedi*, König MS.: Morris, *Cat. Brit. Fossils*, 1st ed., p. 7 [*nomen nudum*]; 2nd ed., 1854, p. 8.
1851. *D. Benstedii*, König: Mantell, *Petrifactions and their Teachings*, p. 49.
1862. *D. Benstedii*, König: Mackie, *Geologist*, vol. v, pp. 401–4, pl. xxii.
1896. *Benstedtia* sp., Seward, *Ann. Bot.*, vol. x, p. 220, pl. xiv, fig. 3.
1911. *Coniferocaulon Benstedii* (König), Stopes, GEOL. MAG., N.S., Dec. V, Vol. VIII, p. 59, fig. (in text).

VI.—THE NAME OF THE 'DRAGON-TREE'.

By MARIE C. STOPES, D.Sc., Ph.D., F.L.S.

WHY should the 'Dragon-tree' have a name at all? Assuredly one of 'nomenclatorial permanency' is impossible for it, for the thing is not a recognizable species. Dr. Knowlton's note on the 'Dragon-tree' (*ante*) is an illustration of the application of the strict laws of nomenclature regardless of common sense. The object of my paper (GEOL. MAG., Dec. V, Vol. VIII, pp. 55–9, 1911) was to show that the plant for some time called *Benstedtia* is *not* a genus in the true sense of the word at all, as it is merely a bit of the woody trunk of one of the higher Conifers. So much Dr. Knowlton accepts—and then discusses its name in the same fashion as is used for true species.

As regards the name, I am sorry I did not make myself quite clear. It was perhaps unwise of me to have mentioned the name *Coniferocaulon* at all, but I thought that this non-committal pseudo-generic name ("the stem of a Conifer"), being already in existence, might be a convenient rubbish-heap for the temporary housing of such uncertain fragments as the 'Dragon-tree'. Dr. Knowlton's quotation hardly represents my attitude towards this name. I said, "Except for historical interest, and for the convenience of having a name by which to designate a special kind of cast of a genus known otherwise (compare the *Knorria*, etc., of *Lepidodendron*), there appears no reason now to give *Benstedtia* a generic name of its own."

My work on the specimen, which any botanist can confirm now I have found the simple method of dealing with such fossils, clearly and finally proved that the supposed genus is merely a bit of wood of a trunk of a Conifer. Dr. Knowlton himself says that the nomenclature of palæobotany "must abide by the same rules" as those applied to recent botany. No botanist gives a generic and specific name to a bit of bark or rotten secondary wood. Palæontology we

know differs very much from modern biology in the nature of the specimens with which it has to deal; but even so, would a vertebrate palæontologist of any standing found a genus and species on the common leg-bone of a mammal because it was too decayed to recognize exactly to which mammal it belonged?

Dr. Knowlton, with the zeal for the technical application of their rules of nomenclature which characterizes a certain school of biologists in America, who take every opportunity these technicalities give them of renaming other people's species, has made himself responsible for *Benstedtia Benstedi*. A genus and species must be capable of diagnosis, and it now devolves on Dr. Knowlton to provide that diagnosis.

NOTICES OF MEMOIRS.

I.—Geological Survey of Southern Rhodesia.

THE following particulars are extracted from the Report of the Director, Mr. H. B. Maufe, for September to December, 1910 (Salisbury, Rhodesia, 1911):—

Headquarters have been established in Bulawayo for the purpose of working in co-operation with the geological and mineralogical section of the Rhodesia Museum. The provision of a suitable topographical map is a question of prime importance. The farm plans compiled by the Surveyor-General on the scale of 400 Cape roods to the inch form the most suitable available basis for the geological field mapping. They are often far from satisfactory as regards topographical details, and the geologist's time will frequently be taken up in inserting the more important surface features.

November and December were spent in actual field mapping in the Enterprise Goldfield, situated to the east of Salisbury. An area of 50 square miles was finished, and a further area traversed, but not completely mapped.

The Enterprise Goldfield lies in a district of metamorphic rocks, extending almost thirty miles slightly north of east of Salisbury, and measuring from north to south eight miles or more. On the north, east, and south it is bounded by granite, which is later than the metamorphic rocks and causes contact alteration in them. The metamorphic rocks are divisible into three groups, as follows:—

(1) A group consisting largely of epidiorite.

(2) An ironstone group, which also includes some limestones.

(3) A group of quartzites and conglomerates.

Each of these groups includes many varieties of rock, some of which occur in two or even three groups, but the groups as a whole are fairly well defined, and seem to correspond with the subdivisions described by Mr. F. P. Mennell in other parts of the country. The greater part of the metamorphic rocks are altered sedimentary rocks—altered conglomerates, sandstones, shales, and limestones. Up to the present the only igneous rocks met with which belong to the metamorphic series are the epidiorites forming the larger portion of group (1). Gold occurs in payable quantities in certain bands of schist intercalated in the epidiorites of group (1). Several mines working these bands are being energetically developed. The ironstone

group, the argillaceous beds of which are often highly charged with sulphides, are being prospected at the present time, and gold is reported to occur in many parts of this group. Group (3), though bearing certain signs of mineralization, seem to have received little attention hitherto. Gold also occurs in quartz veins and stringers traversing the metamorphic rocks, and these are naturally not neglected.

Iron-ore (chiefly hæmatite) is abundant. The huge excavation in Iron Mine Hill on the eastern part of Learig Farm is said to be the work of natives, who formerly smelted the ore for their own use. Limestone is being burnt for lime at Chishawasha. Large deposits, partly magnesian, partly a pure lime, as shown by analysis published in the *Agricultural Journal* for November, 1910, occur on the south side of Kilmuir Farm. A talc-schist of a pleasant dull-green colour is being used successfully for internal decoration in the Chishawasha Mission. The stone, in spite of its schistose structure, carves easily and takes a good polish.

The rocks later in age than the metamorphic series are all of igneous origin. They comprise the granites, together with some allied plutonic rocks more basic in composition, and a younger group of dykes and irregular masses of dolerite. In addition to the immense masses of granite which fringe the district under description, smaller masses are intruded into the metamorphic rocks and frequently crop out in the vleis. Small masses of a more basic plutonic rock are occasionally found in similar positions.

The later dolerite dykes, which are intruded into the granite and metamorphic rocks alike, call for no further description here.

The structure of the metamorphic rocks is exceedingly complex. The rocks have been intensely compressed by forces acting in a north and south direction, and thereby been thrown into folds ranging east and west, but occasionally diverging as much as 20 degrees on either side of these points. The compression has been so intense that the limbs of the folds have been pressed together, and now dip at the same angle and in the same direction.

II.—British Association for the Advancement of Science, Eighty-first Annual Meeting, held at Portsmouth, August 30–September 6, 1911. List of Titles of Papers read in Section C (Geology) and in other Sections bearing upon Geology.

Presidential Address by *A. Harker, F.R.S.*

Clement Reid, F.R.S.—The Geology of Portsmouth and District.

Professor S. H. Reynolds.—Further Work in the Silurian Rocks of the Eastern Mendips.

Dr. A. R. Dwerryhouse.—The Glaciation of the North-East of Ireland.

Dr. W. F. Hume & J. I. Craig.—The Geological Period and Climatic Changes in North-East Africa.

Report of the Committee for the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.

Report of the Committee to consider the preparation of a List of Characteristic Fossils.

Report of the Committee to Investigate the Erratic Blocks of the British Isles and to take measures for their preservation.

Report of the Committee for the investigation of the Igneous and Associated Rocks of Glensaul and Lough Nafooey Areas, Co. Galway.

Joint meeting with Section E: Discussion on the Former Connexion of the Isle of Wight with the Mainland.

Professor J. W. Gregory, F.R.S.—Constructive Waterfalls.

Joint meeting with Sections K and E: Discussion on the Relation of the Present Plant Population of the British Isles to the Glacial Period, opened by *Clement Reid, F.R.S.*

W. B. Wright.—On the Lower Carboniferous Succession in the neighbourhood of Bundoran, S. Donegal.

W. B. Wright.—On the Occurrence of Submerged Forests in certain Lakes in Donegal and the Western Isles of Scotland.

A. R. Horwood.—On some new Rhætic Fossils from Glen Parva, Leicestershire.

A. R. Horwood.—On the Shell-layer in Mollusca. (See GEOL. MAG., September, 1911, p. 406.)

Dr. W. F. Hume.—The First Meteorite Record in Egypt.

R. W. Hooley.—On the Discovery of Remains of *Iguanodon Mantelli* in the Wealden Beds of Brighstone Bay, Isle of Wight, and the adaptation of the pelvic girdle to an erect position and bipedal progression.

Professor E. S. Moore.—Siliceous Oolites and other concretionary structures in the vicinity of State College, Pennsylvania.

Professor E. S. Moore.—On the Pre-Cambrian Beds of Ontario.

Rev. A. Irving.—On the Occurrence of a Freshwater Limestone in the Lower Eocenes of the Northern Flank of the Thames Basin.

Rev. A. Irving.—A Remarkable Sarsen or Greywether.

T. Ross Thomson.—Wealden Ostracoda.

Report of the Committee appointed to enable Mr. E. Greenly to complete his researches on the Composition and Origin of the Crystalline Rocks of Anglesey.

Report of the Committee appointed to excavate Critical Sections in the Palæozoic Rocks of Wales and the West of England.

Report of the Committee appointed to investigate the Microscopical and Chemical Composition of Charnwood Rocks.

Report of the Committee appointed to enable Mr. C. Forster Cooper to examine the Mammalian Fauna in the Miocene Deposits of the Bugti Hills, Baluchistan. (See p. 473.)

Report of the Committee appointed to determine the precise significance of Topographical and Geological Terms used locally in South Africa.

Report of the Committee appointed to investigate the Fossil Flora and Fauna of the Midland Coal-fields.

List of titles of papers read in other Sections bearing upon Geology:—

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Report of Committee on Seismological Investigations.

Professor H. H. Turner.—Note on the Periodogram of Earthquake Frequency, from Seven to Twenty Years.

Maxwell Hall.—Sunspots, Earthquakes, and Rainfall.

Professor O. Petterson.—Great Boundary Waves: Parallactic Tides set up in the Bottom Layers of the Sea by the Moon.

SECTION D.—ZOOLOGY.

Presidential Address by *Professor D'Arcy W. Thompson, C.B.*

Professor G. Elliot Smith, F.R.S.—The Origin of Mammals. Discussion—speakers: *Professor A. Keith, Dr. C. W. Andrews, F.R.S., Dr. Marett Tims.*

Professor Malcolm Laurie.—The Hypostome and Antennæ of a reconstructed Trilobite (*Calymene*).

Professor S. H. Reynolds.—Pleistocene Mustelidæ.

Dr. C. W. Andrews, F.R.S.—The Extinct Reptiles of the Oxford Clay of Peterborough.

Report of the Committee on the Index Animalium.

Dr. Elliott & Miss B. Lindsay.—Remarks on Boring Molluscs.

SECTION E.—GEOGRAPHY.

Professor J. W. Gregory.—Constructive Waterfalls.

SECTION H.—ANTHROPOLOGY.

A. L. Lewis.—Dolmens and Cromlechs.

Report on Artificial Islands in Scottish Lochs.

R. R. Marett.—Pleistocene Man in Jersey.

Dr. A. Keith.—Cranium of the Cro-Magnon Type found by Mr. W. M. Newton in a Gravel Terrace near Dartford.

Dr. A. Keith.—Remains of a Second Skeleton from the 100 foot Terrace at Galley Hill.

Dr. A. Keith.—Fossil Bones of Man discovered by Colonel Willoughby Verner in a Limestone Cave near Ronda, in South Spain.

R. R. Marett.—Cave-hunting in Jersey.

J. R. Mortimer.—Notes on the Stature, etc., of our Ancestors in East Yorkshire.

W. Dale.—Memorials of Prehistoric Man in Hampshire.

O. G. S. Crawfurd.—The Distribution of Types of Implements in the Early Bronze Age in Britain.

Report on Lake Villages near Glastonbury.

H. N. Davies.—Notes of Human Remains of ancient date found at Weston-super-Mare.

Rev. Dr. A. Irving.—Later Finds of Horse and other Prehistoric Mammalian Remains at Bishop's Stortford.

Report on the Excavation of a Prehistoric Site at Bishop's Stortford.

SECTION K.—BOTANY.

Professor F. W. Oliver, F.R.S.—The Life-history of a Pebble Beach.

Professor H. C. Cowles.—A Fifteen-year Study of Advancing Sand-dunes.

Dr. F. J. Lewis.—The Forest Stages represented in the Peat underlying the Moorlands of Britain.

Dr. M. J. Benson.—The Structure of a new type of *Synangium* from the Calciferous Sandstone Beds of Pettycur, Fife, and its bearing on the origin of the seed.

Dr. D. H. Scott, F.R.S.—A Palæozoic Fern and its Relationships (*Zygopteris Grayi*, Williamson).

Professor A. C. Seward, F.R.S.—A Petrified Jurassic Plant from Scotland.

H. Hamshaw Thomas.—Recent Researches on the Jurassic Plants of Yorkshire.

Miss T. Lockhart.—A Contribution to our Knowledge of the Formation of Calcareous Nodules containing Plant-remains.

III.—The Mammalian Fauna in the Miocene Deposits of the Bugti Hills, Baluchistan.[1]

Interim Report of the Committee, consisting of Professor G. C. Bourne (Chairman), Mr. C. Forster Cooper (Secretary), Drs. A. Smith Woodward, A. E. Shipley, C. W. Andrews, and H. F. Gadow, and Professor J. Stanley Gardiner, appointed to enable Mr. C. Forster Cooper to make an examination thereof. (Drawn up by the Secretary.)

THIS expedition arrived in Jacobabad in the middle of January, 1911, and after obtaining the necessary camels, stores, and servants, proceeded into the Bugti territory and arrived in five days at Kumbhi. Here the fossiliferous beds were located and four weeks spent in working out the exposures each side of Kumbhi. The beds were then followed out to the eastward round the Zen Koh range, with varying success, the strata in parts being much disturbed and unsuitable for the preservation of fossils.

During the last four weeks of the expedition an important bone-bed was discovered at Churlando of a different character of deposition to the other beds. Owing to the difficult nature of the excavation, the lack of suitable labour, and to the fact that very heavy rains delayed the work for a week, much still remains to be done in this bed, and the interesting specimens obtained warrant its further exploration.

A considerable collection of mammalian remains was obtained from the various localities which is now in process of development and cleaning in the laboratories of the Natural History branch of the British Museum prior to a detailed examination and description.

The fauna consists largely of Anthracotheres, of which group many species are represented in the collection. Remains of extinct orders of Rhinoceros are also common, including an interesting new genus now in process of examination.

Fragments of small Artiodactyles also occur, but owing to the character of the deposits small forms are seldom preserved. The condition of the remains is unfortunately poor as a rule, partly owing to the weathering and partly to the damage done by contemporary crocodiles at the time of deposition, the remains of these animals being abundant as well as the marks of their teeth on the fossils obtained.

The expedition received much kindness and help from the Government officials, as well as from the ruling chiefs of Dera Bugti.

[1] Read before Section C (Geology), British Association, Portsmouth, September, 1911.

REVIEWS.

I.—The Bighorn Coal-basin, Alberta, Canada. By G. S. Malloch. Memoir No. 9E, Geological Survey, Department of Mines, Canada. Ottawa, 1911.

THE Bighorn Coal-basin is situated in Western Alberta, and was named from the Bighorn range, an outlying portion of the Rocky Mountains that extends from the North Saskatchewan to the Brazeau River. The coal-bearing strata, known as the Kootanie Formation, are of Lower Cretaceous age, and occupy a basin with overlying Upper Cretaceous and Quaternary deposits. The older and underlying strata comprise Jurassic, Triassic, Permian (?), Carboniferous, and Devonian. The discovery of coal was made in 1906 by Mr. D. B. Dowling, and analyses proved that it was well adapted for use in locomotives. Moreover, nine workable seams with an aggregate thickness of 66 feet were subsequently proved, and as much as 88 feet is now recorded in a depth of 2,760 feet. The coal-seams are more regular than the intervening strata. The deposits were accumulated chiefly by rivers, but are in parts of lacustrine and marine origin. The coal was probably formed in peat-bogs. Mr. Malloch gives full particulars of the strata, with lists of fossils, pictorial views, and a geological map.

II.—History of Geology. By Horace B. Woodward, F.R.S., F.G.S. 8vo; pp. 154, 14 portraits. London: Watts & Co. Price 1*s*.

WHATEVER Mr. H. B. Woodward undertakes to do he does well. And in this little book one can clearly see that its omissions are due solely to the limit of its pages. It is full of information of the best and most instructive sort, and can be thoroughly recommended to the youth who after reading one textbook thinks he is master of his subject, or to the older and wiser student who always knows that he has still much to learn. Highly interesting, the reader glides along scarcely noticing that he is taking in intellectual nutrition all the time, and arriving at the end he promptly begins the book over again. The eight chapters are divided into Early Notions about the History of the Earth, the Founders of Geology, Geology in the early part of the Nineteenth Century, Principles of Geology, Surveys, Elucidation of the Older Geological Systems, Palæontology, Archæan and Metamorphic Earth-movements, and Petrology. A short Bibliography and an Index conclude the volume. We notice one atrocious word, 'seaquakes,' one omission, 'Timothy' instead of 'Timothy Abbott' Conrad, and one mistake, 'Richard' instead of 'David' Dale Owen; these we name merely for correction in the subsequent editions. Everybody who pretends to any interest in geology should read this book, and it might well be used in classes wherever geology is taught or referred to.

III.—The Nottingham Coal-field.

Ancient Historical Records relating to the Nottingham Coal-field, 1526 to 1600.—The Historical Manuscripts Commission have recently issued a Report on the Manuscripts of Lord Middleton of Wollaton Hall [Cd. 5567], 1911, price 3*s*. It is well printed (by the *Hereford Times*, Limited], well indexed, but badly sewn, the top sewing having entirely failed to hold the sheets.

In this volume of 746 pages is much interesting matter relating to the early history of the Nottingham Coal-field and indication of a vast deal more which it was impossible to print in a volume of this nature. We find accounts of the sinkings, levels, and getting day by day, with the quantities and prices, wages, and cost of plant. We have rules to be observed by miners in the coal-pits, proposals for carrying coal from Nottingham to London by sea via Hull, improved pumping machinery, and many other matters of considerable interest.

The rules to be observed are as follows:—

"*The Stevers' [sic] Charges.*

"This is our master's commandment that all you stovers of the feild shalle make your just account unto your undermen everye nowne and every nyght what you have gett and sould. For every tyme that you do mys, you must losse iijs. iiijd.

"And for every bourdenne of colles that you do sowfer to be borne from the feilde, you must losse xijd.

"And for everye bordenne of wood the like xijd.

"And that you shale make just messeures betwene the lord and the countre, to make to every halfe rooke[1] ix corfulle,[2] and to every three quarters xiij corfulle, and to every whole rooke xviij cor-full of just and good messeure without fraud, deseate or guile, as you will answere at your perille.

"And if aney one be takene with aney of the pit candels bearinge whome to his house [a fine of] iijs. iiijd.

"And if ane one be takene withe ane of the pit towles [= tools] in his howse, to losse iijs. iiijd.

"And if aney one be taken cuttinge of aney of the pit rowpes or withe aney in his howse, to lowse vjs. viijd.

"And if aney one be taken knotinge[3] in of ane worke, it is fellonie; the must b[e] used at the lordes plesure.

"And for every of these defaultes whosoever he is, it must be taken up [off] of his wages the next Seterday after.

"More, if aney mann do take ane of the lordes money without the comand of him or his offe[ce]res, to losse xs., and so to Departte the towne and the feyld."

Among the accounts are the following:—

"1548, January 19. Paid to Pole and his feylows for dryvynge of a thyrle [= shaft] in the newe leyvell, by daytale, for iiij dayes *dim.* [= ½] . . . . . iiijs. vjd."

[1] A rooke was 2½ yards high and 1 yard square.
[2] The contents of a corf or basket.
[3] Knocking, beating down?

"March 2. Paid to Smaley and one with hym for ij dayes clevyng and makyng of pic-helves . . . . . xvjd."

"June 15. Paid to Smaley for shotyng of a waloer[1] . iiijd."

"June 28. Paid to Burton, Baker, Nyxson and Hill, beyng dryven forth with the dampe of ther pit, for a day worke at the heye way . xvjd."

"Dec. 24. Paid to the pit ryves in parte of recompence for ther paynes for gyeyng [=directing] the workes . . . . xs."

In 1526 a collier seems to have got about thirteen rookes of coal per week, of which the hard was worth eighteenpence and the soft twelve shillings, but by 1548 "the softe cole goeth with the harde cole without anye diversitie of price", and "every rooke is ijs." In 1548 the cost of "syngkynge a pit" was "iiijs. the heght", but how much a 'heght' was in depth does not here appear.

IV.—Brief Notices.

1.—Geological Survey of Sidmouth and Lyme Regis.—A second edition has been issued of the Geological Survey Memoir on the *Geology of the Country near Sidmouth and Lyme Regis*, 1911, price 1*s.* 6*d.* This memoir contains a description of the cliff sections from Otterton Point by Sidmouth and Seaton to Lyme Regis, and of the inland country round Honiton and Axminster. The New Red rocks, the Rhætic beds, Lias, Gault, Upper Greensand, and Chalk are dealt with, and figures of many fossils from the famous locality of Lyme Regis are included. There are also numerous sections, and the superficial deposits, the landslips, and the economic geology are described. The work has been written by Messrs. H. B. Woodward and W. A. E. Ussher, with contributions by Mr. A. J. Jukes-Browne.

2.—"The Growth of a Crystal" was the subject chosen by Principal H. A. Miers for the Eighteenth Robert Boyle Lecture delivered at Oxford in May, 1911 (8vo, pp. 32, Henry Frowde, price 1*s.* net). This is an interesting and popular account (in the highest sense) of what is known concerning the general growth of crystals. Although the author refers to what may be called the vitality of a crystal, he points out that this "is not to be confounded in any way with that of a living plant or creature". Much remains to be done before the mysteries of the growth of crystals can be explained, but the author makes several suggestive remarks that may stimulate further research.

3.—Guide to the Exhibition of Animals, Plants, and Minerals mentioned in the Bible. British Museum (Natural History), Special Guide No. 5, 1911. Price 6*d.*—This work, which contains the latest information on the several subjects of which it treats, will interest a wide circle of general readers as well as students of natural history. The section on minerals has been contributed by the Director of the Museum, Mr. L. Fletcher, who remarks that scarcely any of the specimens mentioned in the Bible were found in Palestine or were

[1] ? straightening, a shaft-head wheel.

brought from localities now known, and that there is still great uncertainty as to the original signification of the Hebrew and Greek names. Most of the specimens were precious stones brought from other lands. The amethyst, beryl, sardonyx, emerald, and agate can be identified. The sapphire appears to have been lapis lazuli. It is doubtful whether the diamond was known when the precious stones in the breastplate of the High Priest were enumerated. Alabaster was an onyx-marble (calcium carbonate), and the material termed brass was generally bronze.

CORRESPONDENCE.

DREIKANTER.

Sir,—Permit me to apologize without delay to Mr. Grabham for having suggested that he was wrong in writing 'a dreikanter'. Whether I was myself in the wrong is another matter. Before venturing on any allusion to other writers I looked the word up, and if I was wrong after all, that fact only strengthens my argument. Surely my point is clear. What I object to is the use of foreign words instead of English ones, especially when accompanied by an alteration in their meaning. The fact that some of us occasionally fall into error in using such words was mentioned incidentally as an additional reason for avoiding them.

Perhaps I should add that I am not responsible for the terms 'tripyramidal' and 'triquetral': they have often been used to express the form of true 'Dreikanter', and those who wish to use that term for facetted pebbles of other shape may be recommended to read Professor J. W. Gregory's address on "The Scientific Misappropriation of Popular Terms" reported in to-day's *Times*.

September 2, 1911. F. A. Bather.

P.S.—In his "Observations on the Magdalen Islands" (Bull. New York State Museum, 149) just to hand, that excellent German scholar, Dr. J. M. Clarke, twice uses yet another variant, namely 'dreikantner'.

September 23, 1911.

FORMATION OF LATERITE.

Sir,—After I forwarded to you Part II, "Microscopical Evidence," of my note on the "Formation of a Laterite from a practically Quartz-free Diabase", which was published in the August number of the Geological Magazine, pp. 353–6, I received from Messrs. Voigt and Hochgesang specially prepared sections cutting through both the diabase and its inner layer of laterite at their junctions.

The following is a short account of the contact between the diabase and its laterite crust:—

Nearing the margin of the undecomposed rock many of the cleavages and the lines of chemical weakness in the plates and prisms of felspar are seen to be filled with films of limonite and are bordered with minute scales of gibbsite.

These cleavage and other lines are still more clearly marked near to the margin, are eroded into and charged with decomposition-products, mainly scales of gibbsite, but with some opaque white and dust-like substances. As the junction is approached the larger felspar prisms and the aggregates of smaller ones gradually break up into small granular non-striated fragments lying in and surrounded by aggregates of scales of gibbsite, interspersed with more or less opaque dust-like substances. Many of the granules are crystal, and their contours remind one of those of sugar crystals dissolving in water. Here and there in the larger plates of felspar aggregates of scales of gibbsite form inlets.

The pyroxene masses in places are changed into aggregates of 'viridite' or of chlorite, but more often the cleavages of otherwise apparently unaltered augite are lined and filled with limonite. Nearer to the margin of the diabase this latter condition steadily increases until close to the contact of the rock and the laterite the masses of augite are changed into reticulations of limonitic products with small unaltered fragments of pyroxene.

Where the rock is actually changing to laterite, all the masses of its augite are altered into reticulations of limonitic oxides of iron with few remnants of more or less unchanged pyroxene, and with relatively few minute aggregates of scales of gibbsite and of dust-like opaque products.

The final change in the slices examined from felspars somewhat corroded to aggregates of gibbsite in parts of them occupied a breadth of less than ·2 of one millimetre, whilst in places, especially where the felspar lies in aggregates of small prisms, the change must be described as abrupt.

The distance between the apparently unaltered diabase and the lateritic aggregate of limonite and gibbsite with few minute fragments of unchanged felspar, some minute granules of secondary quartz, and grains of ilmenite varies in the specimens examined from 1·6 millimetres as a minimum to 3·9 millimetres, or to about one-seventh of an inch, as a maximum. Thus the actual change is mainly, although not entirely, a surface one, the alteration noticed along the cleavage and other lines in the inner parts of the diabase being of very subordinate importance to the superficial ones.

J. B. Harrison.

Science and Agriculture Department,
Georgetown, Demerara,
August 19, 1911.

OBITUARY.

SAMUEL CALVIN, M.A., LL.D.

Born February 2, 1840. Died April 17, 1911.

Samuel Calvin was born in Wigtonshire, Scotland, on February 2, 1840. He went with his parents to America when he was 11 years of age, and received his education at Lenox College, Iowa. When he was 24 years old he enlisted in the Army and served for a few months in the Civil War. He then became a teacher of science in

Lenox College, and afterwards principal of a ward school at Dubuque. In 1874 he was elected to a professorship of natural science in the University of Iowa. Here, at first, he had charge of botany, zoology, geology, and physiology. Later he was made professor of geology, a position which he filled with distinction until his death. He received from Cornell College the degrees of M.A. and LL.D., and from Lenox College the degree of Ph.D.

In 1892 Dr. Calvin was elected State Geologist of Iowa. This position he resigned in 1904 owing to the stress of other duties. However, in 1906, upon the resignation of Professor Wilder, he was again elected State Geologist, and continued to serve until his death. The Iowa Geological Survey under his directorship published about twenty volumes of reports dealing with the geology and mineral resources of the State. Of great scientific value have been his own contributions to the geology of Iowa, especially those papers which have added to our knowledge of the Pleistocene. His most recent scientific publications, which deal with the Aftonian mammalian fauna, have done much to unravel some of the difficult problems of Pleistocene palæontology. In all his scientific work he was thorough, no details were considered trivial; his one desire was to discover truth—to find any facts which could make knowledge clearer, broader, more definite. That he had the power to clothe his thoughts in beautiful language is clearly shown in all his writings.[1]

George F. Kay.

State University of Iowa.

JOHN ROBERT MORTIMER.

Born 1825. Died 1911.

By the death of John Robert Mortimer the geologists of East Yorkshire lose one of the few remaining members of their 'old guard'. Though the chief scientific work of his life was done in the domain of archæology, culminating five years ago in the publication of his great work entitled *Forty Years Researches in British and Saxon Burial Mounds of East Yorkshire*, Mr. Mortimer likewise rendered notable service to geology by his writings and, above all, by bringing together the unrivalled collection of fossils from the Chalk of the Yorkshire Wolds, now housed in the private museum that he built at Driffield.

Mortimer was born in the Wold village of Fimber, and dwelt there until manhood, when he shifted his residence to Driffield, a few miles distant, where the rest of his life was spent, and where he died, on August 19 last, at the ripe age of 86 years. When a child he was of delicate health; indeed, throughout life his health was never robust, but he was endowed with a tough vitality, mental energy, and an indomitable spirit which carried him through many troubles and remained with him up to the last. So lately as the present year he sent a paper to be read at the British Association meeting at Portsmouth, on, "The Stature, etc., of our Ancestors in East Yorkshire". His business of corn merchant and maltster brought him in contact with

[1] Abridged from *Science*, N.S., xxxiv, p. 107. We are indebted to Mr. G. P. Merrill for a copy of this memoir.